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RECOVERY OF SPENT LIME AT THE COLUMBUS WATER SOFTENING AND PURIFICATION WORKS

By Charles P. Hoover

At the Columbus water softening and purification works, lime and soda ash are used to soften the entire water supply of the city, which will average about 20,000,000 gallons per day. Approximately 76 per cent of the lime which is added to the local water absorbs carbon dioxide and is thus converted to calcium carbonate, and the soda ash combining with the sulphate of calcium also forms calcium carbonate, which is practically an insoluble and precipitable compound.[1] The average quantity of lime added to the water, for absorbing carbon dioxide is 7.3 grains per gallon, and the average quantity of soda ash is 7.3 grains per gallon. Every grain of lime which is added to the water precipitates 3.57 grains of calcium carbonate, and every grain of soda ash added to the water produces 0.93 grains of calcium carbonate.

During the year 1914, 3540 tons of lime were used for absorbing carbon dioxide, and 3540 tons of soda ash were used. The addition of these chemicals resulted in the precipitation of 15,930 tons of calcium carbonate, which if dried, burned and reclaimed would produce theoretically 8,921 tons of lime.

It has always been the practice at this plant to settle this calcium carbonate in concrete settling basins, and to periodically wash these settlings into the river below the pumping station intake. The Scioto River is a small stream, and during the summer months,

[1] The remaining 24 per cent of lime precipitates magnesium.

when the flow of water is sluggish, there is not sufficient velocity to carry this material down stream, consequently the bed of the river becomes choked with these settlings and has resulted in some trouble between the city of Columbus and riparian property owners below.

During the summer and fall months, the water of the Scioto River is usually clear, and it is in this season of the year that the water shows its maximum hardness, and, therefore, at this season the maximum quantity of calcium carbonate sludge is produced. During the winter and spring months, when the water from the river is usually very muddy and soft and the quantity of lime sludge is small, the flow of the water in the river is rapid, so that there is no objection to turning this sludge into the river during these periods of the year. The calcium carbonate which is precipitated from the water during the season of the year when the water is clear and hard shows the following analysis.

	per cent
Water	82.0
Gravity	1.126
Silica	4.72
Iron and alumina	2.2
Calcium (as calcium oxide)	45.24
Magnesium (as MgO)	4.27

Theoretically it is possible to produce from this sludge a lime containing 79.48 per cent calcium oxide.

During the winter and fall months, when the river water is muddy, the sludge is so contaminated with mud that there seems to be no economical method for reclamation, but, as has already been explained, this muddy precipitate is only obtained when the river is high, and at such times there is no objection to flushing it into the river.

A plan of recovery for spent lime is contemplated, which will be about as follows:

The settling basin precipitate will be pumped into a thickener, and from the thickener the material will be fed directly into a rotary kiln, where it will be burned into lime. This plan may be changed somewhat in the final design, and the material, after passing through the thickener, may be filtered by means of a suction filter of the continuous type, and then fed into the kiln and burned. Elaborate experiments have been carried on during the past few months, and a picture of the experimental plant, which was used in these experi-

FIG. 1. EXPERIMENTAL KILN FOR RECLAIMING LIME FROM SLUDGE

ments, is shown in figure 1. The kiln is 20 feet long and 34 inches in diameter, and was fired with a Rockwell burner, using fuel oil. 5000 pounds of lime was produced from this kiln, and was used as the softening agent for the entire water softening plant for a period of four hours, during which time 4,000,000 gallons of water were treated. During this large scale test, 42 samples of water were collected, 15 of which were taken at different points in the plant for a period of three hours previous to the time reclaimed lime was used, 20 of which were taken during the time the reclaimed lime was being used, and 15 of which were taken after the use of the reclaimed lime had been stopped, and during which time the high calcium lime, which is ordinarily used, was being used.

The results of these tests indicate very clearly that it was possible to obtain just as good results from this reclaimed lime as with the high calcium lime ordinarily used. The reclaimed lime falls from the kiln in single round lumps, the size ranging from 1 inch to dust, and this is a very convenient size to handle in the present automatic lime weighing scales now in service for weighing lime into the lime slackers. The analysis of the reclaimed lime showed that it contained from 63 to 73 per cent of water soluble calcium oxide, whereas, the lime which is ordinarily purchased at the plant for water softening purposes contains 88 per cent calcium oxide. The interesting feature of this process is that during the period when it is practical to reclaim the spent lime it is possible to produce more lime than is required for use in the softening of water.

There are large limestone quarries within two miles of the water purification works, and limestone containing 90 per cent of calcium carbonate can be purchased at a very low price. The recovery plant will, therefore, be built so that either lime sludge or locally obtained crushed limestone may be burned. During the season of the year when the water is muddy, and it is not practical to reclaim the sludge, limestone will be burned. Samples of the local limestone have been burned in the experimental rotary kiln and lime containing 75.62 per cent of water soluble calcium oxide has been produced. It is estimated that a 65 per cent water soluble calcium oxide lime can be produced from the sludge at a cost of $1.75 per ton, which according to our present contract price is worth $3.40 per ton, and 75 per cent lime can be produced from local limestone at a cost of $2.50 per ton, which will have a value of $4.19 per ton.

At the present time the city of Columbus contracts for lime under the following specifications:

> The city shall pay a bonus of 1½ per cent of the contract price per ton for each 1 per cent by which the water soluble calcium oxide in any car load lot delivered shall exceed 88 per cent, and shall deduct a penalty of 1.5 per cent of the contract price per ton for each 1 per cent by which the water soluble calcium oxide in any carload lot shall be less than 88 per cent.

The contract price of lime is $5.17 per ton; and 4650 tons of 88 per cent lime were used last year. It is estimated that 2500 tons will be produced from lime sludge at a saving of $1.65 per ton, and 3000 tons from local limestone, at a saving of $1.69 per ton; therefore, the installation of this lime plant will result in a saving to the city of approximately $9000, and it is estimated that the plant will cost $30,000.

DISCUSSION

Mr. Charles P. Hoover: The author regrets that he has no drawings with him showing the construction of the Filtros wheel. Briefly, however, this filter is a vacuum operated segmented wheel made out of filtros, a very porous mineral medium. The wheel consists of sixteen segments or compartments, and circulates through a trough holding the lime sludge. Fourteen of the compartments are constantly in communication with a vacuum line, eight of these are always submerged in the lime sludge, and six are exposed to the air, the vacuum withdrawing the moisture during the period of exposure. The dried sludge is scraped off of each compartment just before it advances to the point of submergence into the sludge.

Mr. G. M. Gadsby: Does it take the sludge long to settle?

Mr. Charles P. Hoover: The sludge settles very quickly; in 15 minutes all the sludge is settled from the water.

Mr. Paul Hansen: The speaker does not exactly understand the process that you expect to install. Has not the Dorr thickener a sort of false bottom for carrying away the liquid?

Mr. Charles P Hoover: Yes.

Mr. Paul Hansen: Will not the impurities increase in quantity as the sludge is used over and over again?

Mr. Charles P. Hoover: Yes, they certainly will.

Mr. Paul Hansen: Is that not an objection? If that is so, to what extent is that an unfavorable factor?

Mr. Charles P. Hoover: We do not intend to make lime from the sludge continuously, but for a period of six or eight months in each year. During the rest of the year the water to be softened and purified is so muddy and the sludge so dirty it would be necessary to discard it, probably by forcing it back into the river, and during this period of the year lime will be made from limestone, and in this way an entirely new supply of sludge will be obtained.

Mr. Paul Hansen: To what extent will the impurities accumulate within the six months; that is, how large will be the percentage of impurities at the end of that time?

Mr. Charles P. Hoover: The author is unable to give you offhand any exact figures as to that; but that feature will be overcome or provided against by mixing the sludge with crushed limestone. We contemplate using 85 per cent of the lime sludge, mixed with 15 per cent crushed limestone, and in that way keep up the strength of the lime and thus provide against the accumulation of impurities.

Mr. Frank E. Hale: You said you produced twice as much lime product at your plant as would be necessary, so that for six months you would get enough lime for the year; you will have to discard some of that.

Mr. Charles P. Hoover: We expect to dispose of any excess of lime produced, for agricultural or other purposes.

Mr. John H. Gregory: It is a source of great satisfaction to the speaker that Mr. Hoover is now working out some of the original thoughts brought up at the time the Columbus works were built. It was well known at that time that there was a large quantity of

limestone in and around Columbus, and the question came up as to whether it would be feasible not only to produce lime from the local stone, but also to produce a sufficiently good lime in large quantities. Another factor that was considered at the time the works were designed was the question of recovering some of the spent lime, and it was believed then that it would probably be practicable to install some process for the recovery of some of this lime. The problem which confronted the city, however, was to design a large filtration and water softening plant which could be put under contract and built at the earliest possible date. While it was felt that it would be possible to recover some of the spent lime, the engineers connected with the work did not think that any time should be spent in experimental work to ascertain how best to recover this lime, and, at the same time, they felt that an installation should not be made until some experimental work had been done.

The question of how best to handle the lime sludge deposited in the settling basin was one to which considerable thought was given, and in a general way two methods were outlined. One was to be able to pump the sludge from the bottom of the settling basin, by means of a centrifugal pump, electrically operated, carry it on a scow to some sludge depository where the sludge could be air dried. To permit this method of operation, openings were left in the dividing walls which separated adjacent settling basins, so that it would be possible to float the scow from one basin to another. These openings extended down a few feet below the surface of the water, but were temporarily bricked up and plastered over, for the sake of appearance. Another scheme was that of first drawing off the softened water above the sludge, through a drain running to the raw water suction well, and from which it could be pumped back to the purification works, and in each settling basin an outlet chamber was built for this purpose, it being so arranged that the water, down to a certain depth, could be drawn off, leaving the sludge on the bottom of the basin; the sludge then to be run out through a drain. Up to the present time the sludge has been run out through this drain to the river, but it would be a simple matter to divert the sludge to a settling pond, if desired.

The situation as to the installation of the thickener in the settling basin, to which Mr. Hoover has replied, is not entirely clear, and the speaker would like to ask if it is proposed to put in a device which is sufficiently large to fill the space between the baffle

wall and the dividing wall and which is to operate practically continuously?

Mr. Charles P. Hoover: That is the idea.

Mr. John H. Gregory: That means then that as the sludge, which deposits quickly, comes into the settling basin, it will be drawn out continuously.

Mr. Charles P. Hoover: Yes, continuously.

SOME PROBLEMS OF THE STATE WATER LABORATORY

By L. H. Van Buskirk

Both the physical and chemical examination of water has been made for many years. The importance of industrial water analysis as related to the commercial use of water in the industries, as well as in the home, developed both chemical and physical methods very early. The sanitary analysis must not be considered as a recent development, for even in the time of Hippocrates, and perhaps earlier, the idea was advanced that waters carrying excessive amounts of organic matter had a decidedly ill effect upon the health of the consumer, and examinations to determine the presence of such material were made. The early development was largely chemical and an attempt was made to devise tests which would show the presence of objectionable substances. With the advancement of the science of bacteriology, the bacterial examination of water was started and has proven of untold benefit to the human family. One by one various determinations and methods have been developed and, as time has progressed, many have been relegated to the field of the worthless.

Various investigators working upon methods of water analysis devised numerous schemes for ascertaining the presence of pollution. With this unorganized work it was realized that much of value was being lost, due to the fact that standard methods for both the chemical and bacteriological examination of water were wanting. The first work of importance which was done in this country, tending to a standardization of methods, was by a committee of The American Association for the Advancement of Science. Their report was published in the *Journal of Analytical Chemistry* in 1887. Since that time the American Public Health Association has followed the work done by this committee, and you are all familiar with the standard methods of both chemical and bacteriological water analysis as prepared and published by the American Public Health Association.

This standardization of methods has been indeed a great step forward in making the analytical results of value, not alone in the con-

trol of impending epidemics from the pollution of private water supplies, but also in connection with the operation of water purification plants. The results are now made of comparative value.

The standard methods of water analysis and the reports of various committees not only emphasize the importance of uniform methods of analysis, but also urge extreme care in the collection of the sample. Much difficulty is encountered, due to the improper collection and transportation of samples to the public health laboratory. The importance of immediate examination of samples has been emphasized, and in many laboratories an attempt is made to secure results in the field by having the regular inspectors or engineers carry field outfits with them, or if the proposition is one which includes a large amount of analytical work, it is possible to ship supplies direct to the point at which the samples are to be collected, and the inspector or engineer is thereby enabled to complete the analyses without delay. The value of this sort of work cannot be overestimated. In some instances, however, especially with private supplies, various public health laboratories are not provided with a sufficient number of inspectors or engineers and it is therefore necessary, if the analyses are made at all, to have the health officer or some other public official collect the specimens and submit them to the laboratory. This procedure is very unsatisfactory. Many times the person entrusted with the collection of the sample does not realize the care necessary to prevent accidental contamination. It is greatly to be desired and urged that all samples of water be collected by regular inspectors, experienced in the work in order to insure that the sample is not accidentally contaminated. Under these conditions much more efficient work can be done.

Of course this does not eliminate the time interval necessitated by the shipment of samples to a central laboratory. It does raise, however, another important point and one which is receiving a great deal of attention at the present time, and that is the character of the shipping container used in forwarding bacterial specimens. In Ohio and several other states, small sample bottles are placed in metal cans which in turn are packed in ice in a zinc lined wooden box. The box is provided with a lid and locked. This sort of container with which most are familiar has not proven entirely satisfactory and several state departments have carried on experiments with various sorts of shipping containers and have found that the thermos bottle, or vacuum bottle is satisfactory. Others have used

the idea of the fireless cooker. In the laboratory of the Ohio State Department of Health we have had little trouble with the older type of container which is still maintained in use.

The value of the sanitary analysis of water as done in the routine of the public health laboratory is in many instances very questionable. The samples are received with the information cards many times only partly or not at all filled out. The analytical work is completed and someone is called upon to make a statement regarding the water. Many laymen have the idea that the determinations made are positive and that the chemist and bacteriologist can determine absolutely as to the sanitary quality of the water. Men who have written concerning the analysis of water have stated many times that such is not the case, and that the analysis of water is but a series of tests which tend to indicate the quality of the water. Now when a water is excessively bad, the analytical results are sufficient to condemn the same, or when unquestionably good, the analysis will so indicate. There is, however, a very broad middle field into which a large majority of the waters fall in their analysis. In this field it is extremely difficult to state without knowing the surroundings as to whether the water should be used or should not be used for domestic purposes. Dr. James Ritchie, in an article on the "Present Relationship of Bacteriology to Water-Borne Disease," in the *Journal of State Medicine*, volume 23, page 211, has covered this phase of the subject very nicely and insists that no samples should be run and no interpretations made of analytical results excepting by the person who collected the sample and inspected the surroundings. Only under such condition can the best results be obtained; otherwise the analytical work is of but little value.

Providing we have proper inspection and the collection of the samples by competent men, then the prime object of the examination is to ascertain whether a water is or is not contaminated by excremental organisms. It follows, therefore, that whatever information is derived from the counts of the total number of bacteria present in the water, that information is altogether subsidiary to the facts obtained as to the presence of organisms of intestinal origin. Judgment regarding a water must necessarily turn on a test for *B. coli*. It must be realized, however, that this is an indirect test and that there are many difficulties and defects encountered therewith. It merely points to a possibility that pathogenic organisms may

gain access to the water. The fundamental defect of the method lies in the impossibility of differentiating between the *Bacillus coli* as it occurs in the intestine of man on the one hand and of animals on the other. Various methods for the presumptive testing of waters for *B. coli* have been suggested and recommended. For a long time lactose bile was used quite generally, but as it was realized that lactose bile under certain concentration had an inhibitory effect on the development of *B. coli*, much work has been done to substitute for this some other medium which would secure a larger number with positive gas formation. Recently lactose broth has come into quite general use and is being used in the laboratory of the Ohio State Department of Health. The attitude which is taken on this subject in the Ohio State Department of Health Laboratory is this: *B. coli*, under certain conditions will cause gas formation in lactose bile, in other cases in lactose broth. In either of these media the production of gas indicates the presence of intestinal organisms. This being the case, why is it not a good idea to use both media, and, should positive gas formation be secured in either, the reports should be positive for *B. coli* as far as gas formation is concerned? This system simply asks a very little additional work and at the same time secures a larger number of positive results than would be obtained with but one of the media used, for it has been observed that in many instances gas is present in lactose bile and not in broth, and vice versa. There is more uniformity in the so-called confirmative tests.

The importance of the chemical determinations of the sanitary water analysis is questionable and many laboratories are reducing the number of these determinations, owing to the fact that they consider the bacteriological findings sufficient for proper classification of the water under consideration. In Ohio those samples collected by the departmental engineers are given a complete bacteriological and sanitary chemical examination; those collected by health officers are not so completely analyzed. Until recently, both chemical and bacterial containers were furnished health officers and others not directly connected with the State Department of Health. The same analytical work was done upon these samples as upon those submitted by the regular engineers. Now, however, only bacterial containers are furnished such people. After the bacteriological work has been started, the sample is transferred to the chemical laboratory and there the physical properties and

nitrites, nitrates and chlorine determined. It is believed that sufficient information can be secured from these results and that additional time and expense to the laboratory is unnecessary. This idea has been developed, owing to the fact that it is realized that the bacteriologist and chemist can furnish only a portion of the data on which a judgment regarding a water can be based. Additional information may be secured by an inspection of the local surroundings which play a very important part in the interpretation of any water analysis.

Certain organizations have set standards for drinking waters. The United States Public Health Service standards for drinking waters for common carriers are familiar to all. These standards are more or less confusing and cause considerable trouble in the public health laboratory. For instance, in our own case all samples collected by the engineers are analyzed and the results returned to them for interpretations, as they only are familiar with the surroundings of the source. In our regular routine work on health officers' samples we make the chemical determinations as outlined above and in addition, inoculate both with 1 and 10 cc. portions of the lactose bile and lactose broth. The ordinary confirmatory tests are also run. Our interpretation of the results is based therefore, upon these determinations. The standards as set by the United States Public Health Service are quite different from this, requiring a different method of analysis. Regardless of our knowledge of the local situation and of the character of the supply, we can only interpret the results in accordance with the standards set. Many peculiar circumstances occur and many times embarrassing situations are encountered. The questions which arise, however, from the establishment of standards of purity for drinking waters are interesting. It is questionable of course, as to the advisability of establishing arbitrary standards. It would seem that the question can best be solved by competent inspection and the regular routine sanitary water analysis, as covered by standard methods of water analysis. When we are enabled to have the coöperation of engineers and laboratory men in this class of work, greater advances can be made in the regulation and control of not only public but private water supplies. This is amply demonstrated by the very valuable work which is being done by the chemists and bacteriologists in charge of water purification plants. Not until we have the inspection of sources and collection of samples by regularly em-

ployed men, trained in chemistry and bacteriology, can we hope to secure the greatest efficiency in the public water laboratory.

DISCUSSION

Mr. Frank E. Hale: One point has been brought up in several papers recently, that is, the question of the necessity for certain determinations in water analysis. The speaker wants to go on record as strongly favoring as complete an analysis upon every sample of water as can be made; not meaning each individual sample, but each source of supply. Some laboratories have merely to pass upon the sanitary quality of the supply. In New York City we have additional problems. For example, waters from supposed leaks are sent in. We have to determine whether they are from the city supply or from sewage, or from ground water. The complete analysis is a history of the water, and should be as complete as possible.

There has been mentioned the question of hardness. Usually that is significant in connection with industrial problems, such as boiler waters, dye works, breweries, etc., but it also occasionally has a sanitary significance. For instance one well supply in the borough of Brooklyn has greatly increased in hardness in the last few years, and the probable explanation is the leakage from cesspools into the ground water. In such cases hardness naturally has a sanitary significance. Iron may not have a sanitary significance, but it does have a bearing upon domestic use and use for laundries.

We get around the question of unnecessary work by making a complete analysis four times a year from every source, and sometimes weekly or monthly, depending upon the water examined. A partial analysis is made monthly or weekly, whenever necessary, of those elements that are most important in that particular source. That practice has been in vogue ever since the Mt. Prospect laboratory was established in 1897. It seems that that is the way to get around the question of unnecessary work. Make a complete analysis a certain number of times a year, and cut down the frequent analyses to what is most important and necessary.

Mr. John W. Alvord: Mr. Van Buskirk's paper and his remarks have been centered upon a very important subject; one which in the past has not been honestly enough discussed.

The chemical profession, the sanitary engineering profession, and, in fact, all professions suffer more or less from the misconception that they are exact. Engineers, for instance, are believed to be marvels at mathematical processes, and, therefore, everything they do is looked upon as precise and final. Chemists and bacteriologists come under the same category. A large portion of the public holds this popular misconception. As a matter of fact, it is an entirely erroneous view of our proper functions. We are not exact and we are not precise in the sense that the public imagines. We are a judicial profession. Our real function is to sum up the evidence, array the facts, brief each stage of the case, look over the conditions submitted with proper discrimination and draw general conclusions. The sanitary engineering and chemical profession is a judicial profession much more than it is a precise, exact, or mathematical profession; and the chemical or bacteriological work of the engineer and chemist is primarily the art of using mature judgment and competent opinion on an array of evidence that is often incomplete. It seems to the speaker that we have not only to recognize this fact among ourselves, but that we must be entirely frank with the public about it, much more frank than we have been.

The public shows an improper confidence in us by sending us samples of water from some unknown source, with unknown conditions, and asking us if it is good or bad. That is a common experience of the state laboratory and of all laboratories. What ought we to do under such circumstances? The speaker would say that the frank and the entirely proper thing to do is to mark on the sample, "Insufficient evidence submitted", along with any other determination which might be properly made in the line of duty. The absence of frankness of this kind is responsible for a great deal of the embarrassment that the laboratories are subject to, such as has been discussed by Mr. Van Buskirk, and, until we come to have this kind of frankness with the public, we shall not create in it an understanding of what really are our judicial functions as analysts and as sanitarians. We cannot be led blindfolded into a field, allowed to pick one flower, and then, carrying it into the laboratory, be made to tell what kind of hay is going to be harvested, or what kind of botanical products are derivable from the field. Let us be honest and frank and say so. Let us stop misconceptions on the part of the public. It is folly to allow the public to mislead itself, and yet we will all find at times samples of waters sent, with in-

sufficient data from which a fair determination cannot be made, and an opinion is returned in exceedingly cautious language, it is true, but without the frank admission, which should be written on every such sample, in these words, "Insufficient evidence submitted for final opinion".

Mr. F. W. Mohlman: The speaker was especially interested in Mr. Van Buskirk's remarks about educating the laity to comprehend what water analysis means, and also his remarks concerning inspections. At the Illinois State Water Survey probably 75 per cent of the samples are from wells in small towns, and of that 75 per cent we usually find that 10 per cent are not collected according to instructions. Physicians are the worst offenders. Instructions are put into every sample container, so that there is no reason for them to make a mistake in collecting samples. It seems that the physicians are as much to blame as the water analysts in neglecting their duty toward the public, in not explaining what the analysis means, and also in not following directions in the collection of the samples. We had an instance of what this means in Illinois a short time ago, in connection with a typhoid fever epidemic. The sample containers were sent to a physician, the president of the local board of health, who collected the samples and sent them in. The usual analysis comprises both a sanitary and a bacteriological analysis. Specific instructions were given in this instance. This physician sent in three samples from three wells for bacteriological analysis, and three samples from three other wells for sanitary and chemical analysis. The practice in ordinary cases would be to refuse to give an opinion on any of these waters. It was necessary to postpone the report until we could get the waters properly collected. This delay was wholly due to the carelessness of the town physicians. We have found them to be the worst offenders.

Mr. Charles P. Hoover: The speaker had rather a funny experience at Columbus recently. The water department analyzed about 2000 private wells and about 35 per cent of them were pronounced bad. One day a physician requested a sterilized bottle, stating that he would like to have the water from his well examined. He received the bottle, and the following day sent the sample to the laboratory for analysis. For some unknown reason it was felt that

there was something wrong about the fellow, and that he was trying to put something over on the laboratory. A very simple chemical test was made of the water which he submitted, and it showed that the water was not well water but the city filtered product. Lime and soda ash are used to soften the water supply of Columbus, and consequently the water has an alkaline reaction, and gives a red color with phenolphthalein, so that it is very easy to identify it. As soon as it was found that it was city water, and not well water as represented, no trouble was taken to make a bacterial analysis, but a letter was written to the wise gentleman saying that his sample of water had been received, and that the analysis showed it to be the best sample of water that had ever been submitted to our laboratory for analysis.

Mr. Arthur R. Taylor: The speaker was very much interested in Mr. Van Buskirk's paper, and some of the things he relates as to the analysis of water, and its relation to water supply problems, recall an incident which occurred recently before the Public Service Commission of one of our largest states on a question of the purity of a certain water supply. One of the members of the commission was evidently bent on studying water analysis. On being told that we could not distinguish between intestinal organism, whether from human or animal source, he seemed to think that if such were the case he could not see what use there was in water analysis.

Hon. James J. Powis:[1] The speaker has been very much interested in the paper of Mr. Van Buskirk, and especially in the statement that the railroads of the United States were beginning to see the necessity of sanitation, and to secure proper conditions, and were commencing to show an interest in the problem of securing pure water supplies. This is especially interesting for this reason: for many years, according to the statistics, the railroad reports of the United States, the railroads of this country have transported some 800,000,000 people per year, and the methods of the disposing of the human excreta from these trains is upon the railroad tracks and the highways, often over sections of the country where the watersheds or natural drainage, wash this excreta into the streams.

[1] State Senator of New York State.

It would be a grand thing if a consensus of opinion of this distinguished body would be to encourage the railroads to cease this mighty pollution which they can very easily do. The inventive minds of the country will very quickly provide them with means if they show any desire to adopt them. That the railroads, boats, and highways of this country should furnish pollution continuously, and that the streams and rains should carry it into the waters of every state wherein they run, seems monstrous in this age.

The Chairman: That is a point that is well taken. Most of us are familiar with what is being done in the west for the alleviation of such sources of contamination of water supply. There are state boards of health and a national board of health in this country and in Canada who are looking after matters of that kind.

Mr. Chester G. Wigley: The presentation of facts by Mr. Van Buskirk is very interesting to anyone connected with a state board of health. It is a common thing to find that the ordinary man sends a sample of water to the laboratory, and looks upon the determination made from examination of the water as something akin to the black art, thinking that a man can take a sample of water, often times submitted in a pill bottle, and, by some peculiar process of examination, tell where it came from, and what came with it, and everything else. But the water works man has gotten beyond that point, at least in New Jersey. The container that is supplied by the State Department of Health is very carefully prepared, sterilized, and sent out with certain slips supplying certain information, exact information, as to how to obtain the sample for examination. If a sample of water is sent in an ordinary preserving jar, the general attitude of the State Department of Health is to reply to the man that the sample is unsatisfactory for analysis, and to proceed to deposit it in the sink. The matter is then taken under consideration, and if it appears that there is any necessity for the collection of a sample, a man is sent to check up the conditions. It is a rather difficult proposition to educate the people along these lines, because the public water works official is not as permanent in his tenure of office as he should be in a great many ways. By the time one man is educated a new man is put upon the job. It has been found that probably the most valuable data are obtained not so much by the chemical analyses that are made

in the laboratory as by the actual inspection of the water supplies in the state. Some of these inspections have been startling in a way, as showing potential possibilities of pollution; for instance, there was recently found one water supply that, as far as known, was obtained from very deep wells; upon investigation it was found that there was a connection with a brook that was very badly polluted. Fortunately this had not been used, but had it been used the possibility of an epidemic from typhoid would have been a very serious matter. This leads to a consideration of the standards that are required for a water that is used upon a public carrier. The experience in some cases has been in a way contrary to the ordinary experience; in some instances analyses have shown that the water supply would be entirely satisfactory, and upon examination of the water supply it was found that it was constructed and maintained in such a way as to be, by our standards, a very dangerous supply to draw water from. This relates more particularly to the small water supplies used by railroads at small stations where there is not a public water supply. The standards of the federal government are but little more than a yard stick or measuring device which is applied to any given water supply a certain number of times, and in that way a measure is obtained of the quality of the water. In the speaker's mind there has been slowly forming the thought that a better and more satisfactory way of measuring the water supply, and the quality of the water supply, is to depend not so much upon the chemical and sanitary analyses of the water as upon the basis of a system somewhat similar to that used in scoring dairies, which would be a summation of the conditions and factors that are of importance in the maintenance of a proper water supply.

MT. KISCO SEWAGE DISPOSAL PLANT[1]

By T. D. L. Coffin and F. E. Hale

DESCRIPTION

Under authority of an act of the New York State legislature of 1907, the city of New York and the village of Mt. Kisco entered into an agreement whereby the city bound itself to build and forever operate a pumping station and sewage disposal plant to care for the sewage of the entire village and in return therefor, the village agreed to construct the necessary trunk and lateral sewers, and to deliver to the pumping station all the sewage of the village.

The village of Mt. Kisco, population 3000, is located in Westchester County, 37 miles from New York City, upon the tributary area of Kisco River, an affluent of Croton Lake entering that reservoir about three miles from the Croton Aqueduct gate house. Owing to this location, and particularly to the topography and character of the soil, which in much of the village is unsuited to local disposal of sewage, the city considered it advantageous to enter into this agreement so favorable to the village.

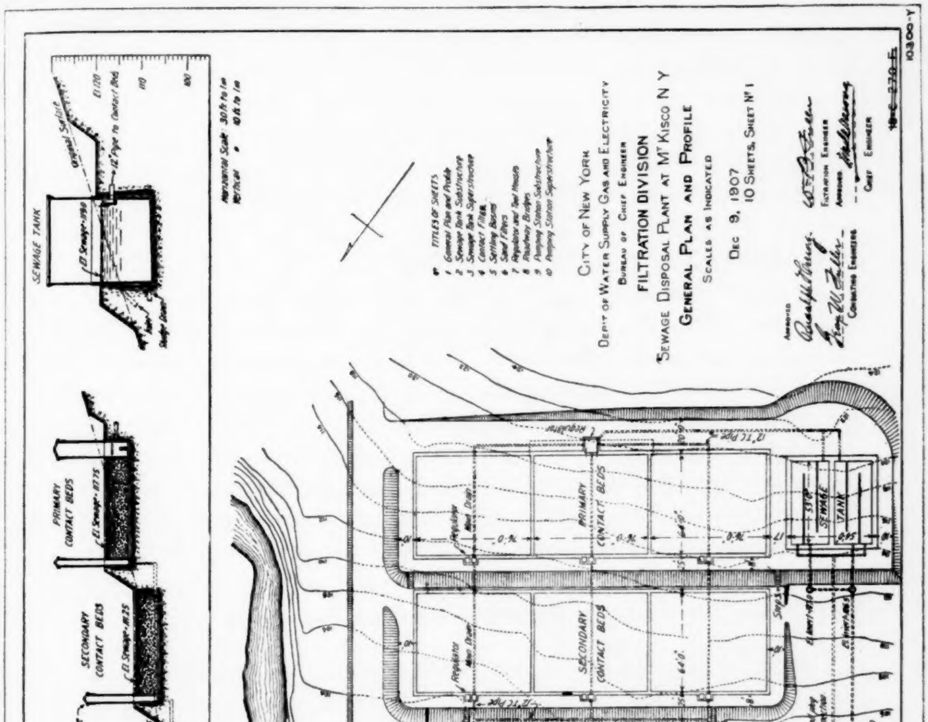
Plans were prepared for the entire work, and, in the autumn of 1909, work was started, and the plant was put in operation February 1, 1913, the village at that time having completed a portion of one of the three trunk lines of sewers.

The accompanying plan shows the general arrangement of the plant.

PUMPING STATION

The three trunk sewers enter a receiving chamber provided with shear gates so that any one of the trunks may be shut off from the screen chamber in case of a break in the line. Entering the screen chamber, the sewage passes inclined bar screens spaced $1\frac{1}{2}$ inches in the clear, then through similar screens spaced $\frac{5}{8}$ inch in the clear into a storage compartment 20 feet by 8 feet, having an ordinary fluctuation in water level of 5 feet 6 inches though the sewage

[1] **Description of plant by T. D. L. Coffin. Analytical by F. E. Hale.**


City of New York
Dep't of Water Supply Gas and Electricity
Bureau of Chief Engineer
FILTRATION DIVISION
Sewage Disposal Plant at Mt Kisco N Y
General Plan and Profile
Scales as Indicated
Dec 9, 1907
10 Sheets, Sheet No 1
SEWAGE TANK
PRIMARY CONTACT BEDS
SECONDARY CONTACT BEDS
SETTLING BASINS
SAND FILTER BEDS
KISCO RIVER
Roadway
TOOL HOUSE

may rise 11 feet above normal before overflowing the receiving chamber. Separated from the screen chamber by a solid concrete wall, is the pump sump 10 feet by 22 feet by 19 feet in height. In this chamber are mounted two horizontal high efficiency, centrifugal pumps, of a capacity of 350 gallons per minute each and one horizontal, low efficiency, centrifugal pump, of a capacity of 450 gallons per minute. These pumps discharge against a head of 45 feet due to the elevation of the point of discharge and to the friction in the force main. The two pumps first mentioned are operated by 10 h.p., two phase, 60 cycle, 220 volt, 900 r.p.m. induction motors. These motors are started and stopped by the rising and falling of the sewage in the screen chamber. The third, or auxiliary, pump is operated by a 20 h.p. horizontal, gasoline driven engine. This pump is held in reserve for use when the electrically operated apparatus is undergoing repair; when there is an interruption in the electrical power service, or when, due to high water over the trunk sewers, there is an infiltration of ground water which, coupled with the normal sewage flow, is in excess of the capacity of the electrically operated pumps.

SEWAGE TANK

The sewage is discharged from the pumping station through a 10-inch cast iron force main 3700 feet in length to the sewage tank. This is an enclosed, dual, concrete chamber, each compartment having a sewage capacity of 100,000 gallons and an average depth of 10 feet 3 inches below the flow line. Two baffle walls divide each chamber into three compartments 8 feet wide. The pumped sewage enters the chamber 5 feet above the bottom and flows the entire length of the baffled chamber, or 156 feet, to the outlet weir, so constructed that the discharge is drawn from a point 24 inches below the surface. Between the two compartments there is a wall of dimensions ample to withstand the pressure resulting from one full and one empty chamber. Twenty-five piers, together with the side walls, support the superstructure. The bottoms of the tanks have a drop of 6 inches toward a depression reaching a foot in depth at the 10-inch sluice gate provided for discharging the sludge from the chamber. Each chamber is provided with a 6-inch supernatant liquid drain connecting with the second contact bed. Over the top of the division wall, and two of the baffle walls, and about the sides of the building, concrete platforms, or walks, are provided. The superstructure is of concrete, the roof only being reinforced.

REGULATOR HOUSE

From the outlet weir of the sewage tank, the liquid is drawn through a 12-inch terra cotta drain to the regulator house, in which is an Ansonia apparatus for discharging the liquid into one of three contact beds. Sewage may be discharged into all three contact beds in rotation, or into any two contact beds alternately. As the pumpage of sewage is intermittent with low sewage flows, it is apparent that the duration of discharge into any contact bed of the first series is variable.

CONTACT BEDS

There are six contact beds: three primary, receiving the sewage after tankage, and three secondary, receiving the effluent of the primary contact beds. All six beds are identical in size and detail. Each bed is 76 feet by 64 feet in area, has an end depth of 4 feet 6 inches and a center depth of 5 feet. Through the center of each bed there is a depression 15 inches wide with a depth increasing from 6 inches to 12 inches from inlet to outlet end. The entire bottom of the bed is covered with parallel rows of 6-inch half round tile, with open joints. A concrete cover over the center drain rests on top of these tile collectors. The bed is filled with broken stone to the top of the side walls, although the flow line is 6 inches below these walls. As the inlet and outlet are at the bottom, this depressed flow line prevents aerial nuisance. The sewage capacity of each contact bed is about 50,000 gallons. An Ansonia regulator at the end of the main drain discharges the sewage from the primary to the secondary contact beds and from the secondary beds into two settling tanks. This apparatus is such that the height to which any bed is filled may be predetermined, and one, two, or three beds of either series may be operated, but the time of contact depends upon the time of filling of the next bed in series. Stated differently, the time of contact depends upon the rate of sewage flow.

SETTLING BASINS

The effluent of the second contact bed is discharged into one or both of two settling tanks, each having a surface area 2160 square feet and a depth below the overflow lip varying from 3 to 4 feet. These basins discharge into a common channel from which the flow

may be directed onto one of three sand filters. The deposit from the settling basin may be drawn off to sludge filters as required.

SAND FILTERS

The sand filters, three in number, have a combined sand area of half an acre, a sand depth of 30 inches, and an effective size of 0.35 mm. Many analyses of the sand were made at the bank and by careful selection a very uniform sand was secured. These filters are enclosed with earth embankments and at the intersection of the slopes and sand surface a 3-inch by 10-inch hard pine plank, placed vertically, marks the limit of the filtering area and prevents the washing of silt on to the sand surface. The collector system of each bed consists of 300 feet of 4-inch open joint tile, surrounded with gravel and discharging into a 10-inch collector laid longitudinally through the bottom of the bed.

CHLORINATING APPARATUS

At the manhole where the three collectors join, a bleach plant is placed and the chlorinated effluent, after a short detention in an open basin, is discharged into Kisco River. The amount of chlorine applied varies from 10 to 20 p.p.m., depending upon the rate of sewage flow.

SLUDGE DISPOSAL

The sludge from the sewage tank is discharged by gravity flow into one of five sludge pits; i.e., hemlock sheathed trenches, 80 feet long, 10 feet deep and 6 feet wide. At the discharge end of each trench there is an 8-inch tile pipe with vertical inlet with lip to be set at any desired elevation. This arrangement permits of drawing off the partially clarified liquid from the top and leaving the sludge at the bottom. It is the intention to abandon the trenches when filled with sludge. The liquid from these trenches, as well as the sludge from the settling basins, is discharged upon a sand filter 100 feet by 100 feet in area and 12 to 18 inches deep with a trench through the center extending down through hardpan into a waterbearing stratum beneath. From this bed there is an overflow weir with bleach tank above so that excess water may be chlorinated and discharged onto low lying land which eventually drains to a tributary of Kisco River, a quarter of a mile distant.

The plans from which this plant was built were prepared under the direction of Wm. B. Fuller, of Hering and Fuller, consulting engineers, and I. M. de Varona, chief engineer, bureau of water supply. John W. Heller, of Newark, N. J., was the general contractor.

The cost of the plant was as follows:

Pumping station building and disposal plant	$64,526 00
Sludge trenches and filters, fences, etc	7,027.00

Included in the first item is $16,000 for roadway and fencing.

In general, though the plant has proved most satisfactory in operation, delivering a clear, non-putrescible, practically germless effluent, there are minor details which, in the light of operating experience, might be modified to advantage. This and the following statements are without bias, and solely as an aid to others who may be called upon to design somewhat similar plants.

1. The screen chamber at the pumping station does not afford convenient means for the removal and disposal of screenings. These must be hoisted to the surface and carted in a watertight scavenger's wagon to a point of ultimate disposal. Had the electrically operated pumps had larger waterways, though their economy of power would have been somewhat lessened, the amount of material to be removed by hand would have been decreased. The amount of sludge and screenings to be removed amounts to about 16 cubic yards per month and it is necessary to dismantle the smaller pumps and clean their waterways about twice a month.

2. On one occasion the regulating apparatus between the sewage tank and the primary contact beds stuck during the night and an overflow of sewage occurred. An overflow lip directly to the surface of a contact bed would obviate this condition.

3. On more than one occasion, the regulating apparatus between the contact beds has failed in its operation and the beds have overflowed. A weir between each bed is indicated as a precautionary measure.

4. From an earlier statement and from remarks to follow by Dr. Hale, it is apparent that the primary contact beds serve as charging chambers for the secondary beds rather than as contact beds. An arrangement of piping to carry the tank effluent to a plane near the stone surface and there permit the liquid to trickle over the stone might increase the efficiency of these beds.

5. Hemlock is not a sufficiently lasting material as sheeting for the sludge trenches.

6. Last summer, the sand filters without thorough draining were horse cultivated. This by winter caused a compacting of the upper layers of sand which materially lessened the rate of filtration, and reduced the nitrification previously secured. A thorough hand cultivation when dry was necessary to restore these filters and in future it is intended to scrape, cultivate, or otherwise work these beds only when in a thoroughly dry condition.

ANALYTICAL

Samples are taken once a week upon the same day, representing each stage of treatment, and given complete examination, physical, chemical and bacteriological. The chlorinated effluent, however, is examined only bacteriologically, but is usually sampled daily, Sundays excepted. The determinations made consist of turbidity, Kjeldahl nitrogen, (in solution, in suspension, and total), free ammonia, nitrite, nitrate, total solids, suspended solids, loss on ignition, fixed solids, chlorine, free carbonic acid, putrescibility, bacteria at 37°C., and presumptive test for *B. coli*.

Methods need only slight comment. Turbidity is determined as in water analysis by the candle turbidimeter. The nitrogens are determined by distillation, not direct nesslerization; nitrate by phenol-sulphonic acid method; suspended solids by the Gooch crucible; carbonic acid by titration; putrescibility by varying dilutions with aerated distilled water and incubation at 37°C., for five days. The bacteria count is the total growing in one day on agar at 37°C.; and the *B. coli* is the presumptive test of 20 per cent gas within three days in lactose peptone bile at 37°C., dilutions of sewage by tenths being tested up to the millionth of a cubic centimeter.

The following table (1) shows the average figures for the year 1915 together with percentage removal at each stage of the amount of material entering that stage and also the total percentage removal of the complete plant.

It will be noticed at once that the "septic tank", a term commonly used to describe several forms of sewage tanks in which septic action takes place, and the sand filters perform the heaviest amount of work. The septic tank is particularly efficient. It removed 81 per cent of the suspended solids as weighed, 66 per cent expressed

TABLE 1

The City of New York, Department of Water Supply, Gas and Electricity, Mt. Kisco Laboratory, Mt. Kisco Sewage Disposal Plant, 1915
Averages and Amount of Purification.

SAMPLE	PHYSICAL EXAMINATION		CHEMICAL ANALYSIS (PARTS PER MILLION)													BACTERIOLOGICAL EXAMINATION								
			Nitrogen as														B. coli.							
			Kjeldahl ammonia																					
Place of collection	Turbidity (parts per million of silica)	Color (parts per million of platinum)	In solution	In suspension	Total	Free ammonia	Nitrite	Nitrate	Total solids	Suspended solids	Loss on ignition	Fixed solids	Chlorine	Putrescibility (oxygen demand)	Free carbonic acid	Number of bacteria per cc. 24 hours at 37.5° C.	cc .001	cc. .0001	cc. .00001	cc. .000001	cc. .01	cc. 0.1	cc. 1	cc. 10
														O	CO_2									
Average analyses																	%	%	%	%	%	%	%	%
Raw sewage (P.S.)	239		14.1	10.5	24.6	23.9	0.125	0.52	575	231	276	299	49	153	40.8	1,480,000	37	84	98	100	100	100	100	100
Septic tank effluent	81		3.9	3 0	6.9	12.2	0 058	0.31	307	44	104	203	41	90	45 0	400,000	22	49	92	100	100	100	100	100
First contact bed effluent	83		4.3	3.2	7.5	12.6	0.062	0.31	323	45	106	217	45	81	44.5	560,000	20	59	92	100	100	100	100	100
Second contact bed effluent	63		3.6	2.8	6.4	10.9	0.111	0.29	288	26	77	211	45	45	48.6	470,000	16	59	92	100	100	100	100	100
Settling basin effluent	53		2.8	2.3	5.1	9.5	0.072	0.15	279	21	69	210	46	27	48.5	460,000	14	49	90	100	100	100	100	100
Sand filter effluent	10	27			0.419	3.74	0.033	2.74	299		64	235	46	0	66.7	38,000	0	10	60	83	100	100	100	100
Filter effluent chlorinated																38						4	8	39
Percentage removal for each stage																								
	%		%	%	%	%			%	%	%	%		%	%	%								%
Septic tank	66		72	71	72	49			47	81	62	32		41	+10	72								40
First contact bed	+2		+10	+7	+9	+3			+5	+2	+2	+7		−10	−1	+40								−4
Second contact bed	24		16	13	15	13			11	58	27	3		44	+9	16								15
Settling basin	16		22	18	20	13			3	19	10	0		40	0	2								13
Sand filter	81				92	61			+7		7	+12		100	+38	92								91
Chlorination																99.9								99 997
Total plant	96				98	84		+527	48		77			100	+63	99.997								99.9999

as turbidity, 71 per cent expressed as nitrogen of suspended matters. Considering other important determinations there were removed 72 per cent organic nitrogen, 41 per cent putrescible matter, 72 per cent bacteria, and 40 per cent *B. coli.*

Owing to design the first contact beds have accomplished practically nothing as to purification, most of the figures showing a slight increase. They do serve as storage for regulation of flow into the second contact beds. The second contact beds show some purification of the matter reaching them, 24 per cent removal of turbidity, 58 per cent suspended solids, 13 per cent nitrogen of suspended matter, 15 per cent of organic nitrogen, 44 per cent putrescible matter, 16 per cent bacteria, and 15 per cent *B. coli.* Apparently these contact beds so worked over the material that purification progressed to about an equal extent in the settling basins.

The removal in the settling basins was 16 per cent turbidity, 19 per cent suspended solids, 18 per cent nitrogen of suspended solids, also 20 per cent organic nitrogen, 40 per cent putrescible matter, 2 per cent bacteria, 13 per cent *B. coli.*

The sand filters performed excellent work. Of the turbidity 81 per cent was removed, organic nitrogen 92 per cent, putrescible matter 100 per cent, bacteria 92 per cent, *B. coli* 91 per cent. It will be noticed that there was an increase in fixed solids due to fixation of oxygen as nitrate and of carbonic acid as carbonates.

Chlorination of the effluent removed 99.9 per cent of the bacteria and 99.997 per cent of the *B. coli.*

The percentage removal for the total plant referred to the raw sewage was as follows:

Turbidity 96 per cent, organic nitrogen 98 per cent, putrescible matter 100 per cent, bacteria 99.997 per cent and *B. coli* 99.9999 per cent. The chlorinated effluent, except for free ammonia, would compare well with many drinking waters, usually being clear, with hardly noticeable color, free from bacteria and with the absence of *B. coli* in 10 cc. It would, however, taste of chlorine.

The following table (2) compares the loss of nitrogen at each stage with the production of free carbonic acid.

It would appear that the consumption of nitrogenous material with the loss of nitrogen as a gas is a more important function of the septic process than the consumption of carbonaceous material.

Both nitrogenous and carbonaceous material appear to have been abundantly consumed in the filter beds. Of the total nitrogen

worked over by the sand filters 25 per cent was oxidized to nitrate and 75 per cent lost as a gas. This same ratio was true of a trickling filter effluent at another plant. Judging from the nitrogen loss, the septic tank produced 70 per cent of the total chemical purification effected, the contact beds and settling basins 11 per cent, and the sand filters 19 per cent.

The purification previous to chlorination is well represented upon the accompanying diagram, No. 1, in which the abscissa represents the average time for each stage in the purification. Different scales of magnitude are employed for the various determinations on the ordinate in order to bring out the proper correlation.

The best measure of purification is the putrescibility, expressed as parts per million of oxygen demand. This line shows how the organic material has been worked over and stabilized even when chemical analyses do not show equal results.

TABLE 2

Removal of total nitrogen and production of carbonic acid

	TOTAL NITROGEN LOSS	PER CENT REMOVAL OF TOTAL NITROGEN	INCREASE OF CARBONIC ACID
	ppm.	*per cent*	*ppm.*
Septic tank	−29.6	70	+ 4.2
First contact bed	+ 1.0	?	− 0.5
Second contact bed	− 2.8	4	+ 4.1
Settling basin	− 2.9	7	− 0.1
Sand filters	− 7.9	19	+18.2

The septic tank shows a reduction in suspended and total solids, turbidity, organic nitrogen of suspended matter, and free ammonia proportional to the drop in putrescibility, and even a greater drop in organic nitrogen, also a slight increase in carbonic acid.

The first contact beds show a slight drop in putrescibility although chemically there appears to be no purification, the average figures showing a slight increase probably due to chance in sampling a very variable sewage.

The second contact beds show a considerable drop in putrescibility although only a slight decrease in chemical determinations and a slight increase in carbonic acid. However, despite the slight chemical changes, the decrease in putrescibility of the combined contact beds is nearly equal to that produced by the septic tank and, moreover, the contact beds have apparently such an influence on

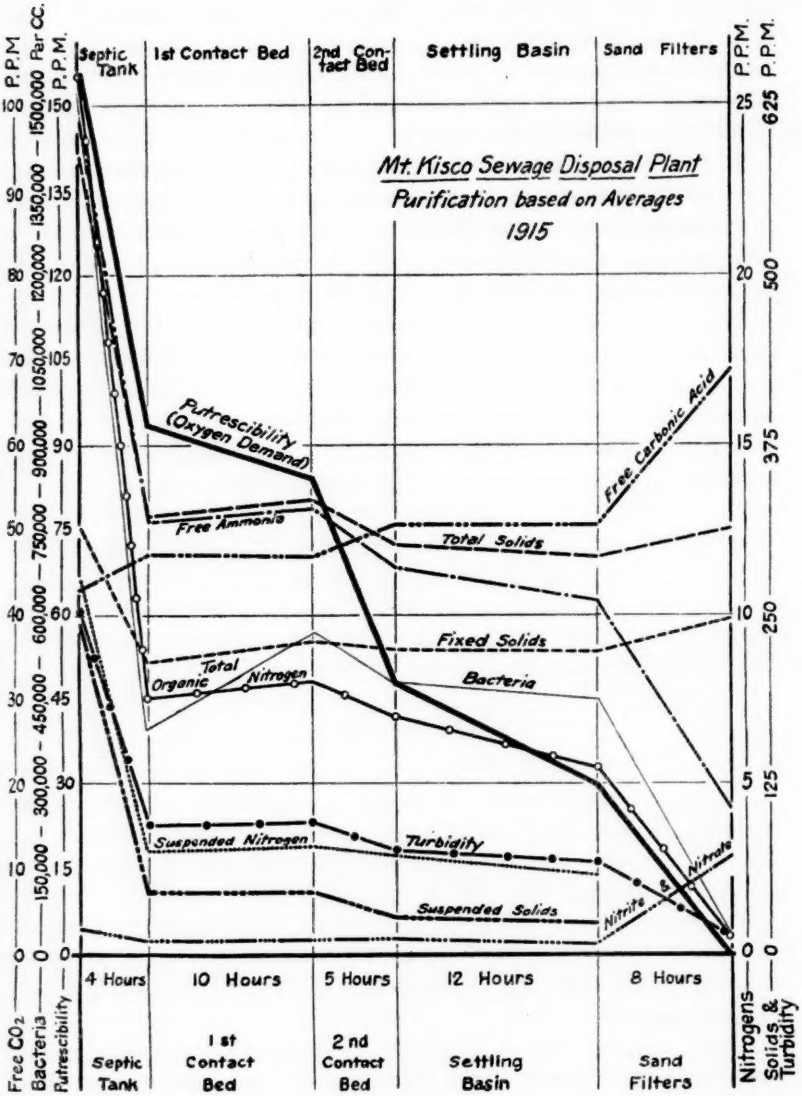

Mt. Kisco Sewage Disposal Plant
Purification based on Averages
1915
Septic Tank
1st Contact Bed
2nd Contact Bed
Settling Basin
Sand Filters
4 Hours
10 Hours
5 Hours
12 Hours
8 Hours
Free CO2 — P.P.M.
Bacteria — Per CC.
Putrescibility — P.P.M.
Nitrogens — P.P.M.
Solids & Turbidity — P.P.M.
Putrescibility (Oxygen Demand)
Free Ammonia
Total Solids
Free Carbonic Acid
Fixed Solids
Total Organic Nitrogen
Bacteria
Suspended Nitrogen
Turbidity
Suspended Solids
Nitrite & Nitrate

DIAGRAM 1

the sewage that purification continues in the settling basins as shown by a considerable drop in putrescibility, although accompanied again by only slight changes in chemical analysis. This result is not due to sedimentation merely, as is shown by the turbidity and solids figures.

The sand filters complete the drop in putrescibility accompanied by a sharp decrease in turbidity, free ammonia and organic nitrogen, and an increase in nitrate, carbonic acid, total and fixed solids, the last two due to the fixation of oxygen and carbonic acid.

While there seems to be no particular reason why it should be so, it is noticeable that the total bacteria (37°C.) line follows in a general manner the other lines, showing a heavy drop in the septic tank, an increase in the first contact beds, a slight decrease in the second contact beds and sedimentation tanks, and a sharp drop in the sand filters. Probably there is a connection between food value and its amount and the total number of bacteria. The test for *B. coli* shows a corresponding decrease although not charted.

The finishing touch to the purification is given by the chlorination. Its efficiency is shown by daily analyses as embodied in the following table (3):

TABLE 3

Efficiency of chlorination as shown by the number of samples with varying amounts of bacteria in the chlorinated effluent

BACTERIA PER CC. AGAR AT 37°C.	NUMBER OF SAMPLES	PER CENT OF TOTAL SAMPLES EXAMINED
		per cent
0	103	36
1–10	81	29
11–50	81	28
51–100	15	5
101–2000	6	2
	286	100

The plant works under great disadvantages in that it treats an extremely variable sewage, from strong sewage to almost pure ground water. This undoubtedly interferes with proper bacterial growth and activity. The following diagram (No. 2) shows the fluctuations throughout the year of the analyses of the sand filter effluents.

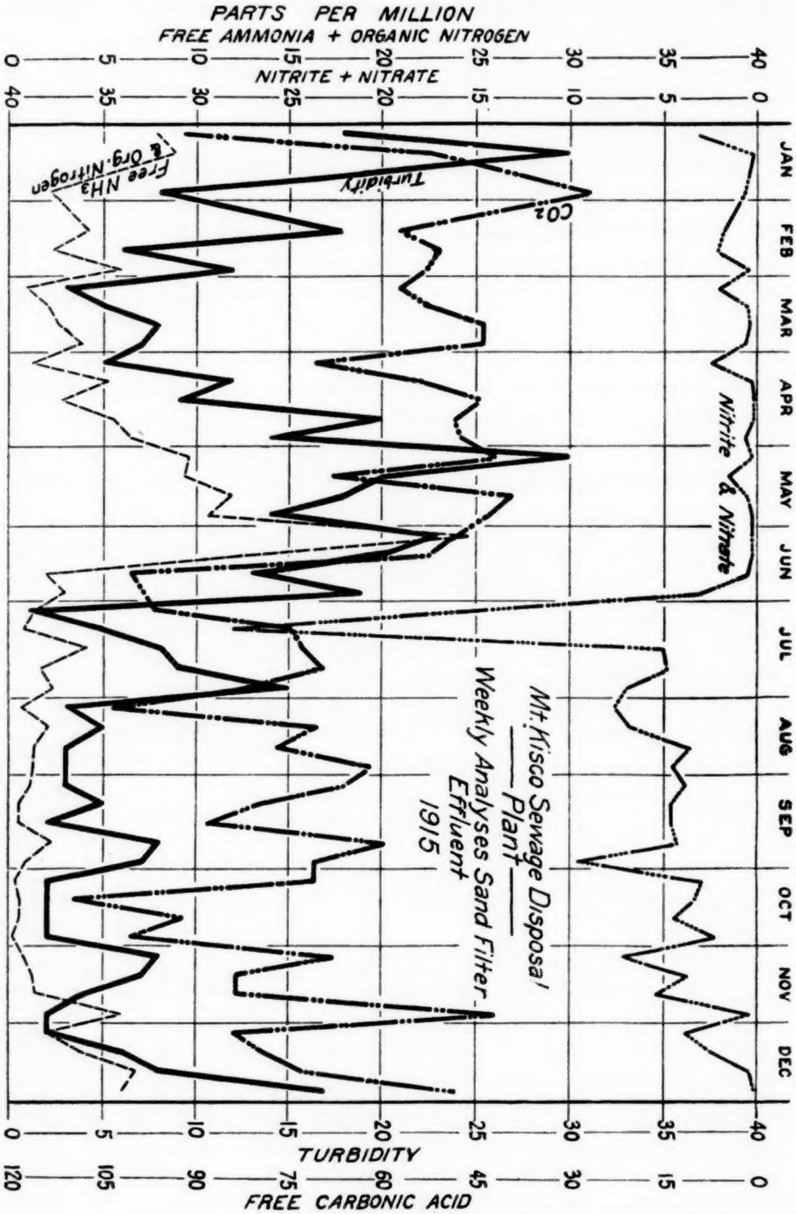

PARTS PER MILLION
FREE AMMONIA + ORGANIC NITROGEN
NITRITE + NITRATE
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Free NH3 & Org. Nitrogen
Turbidity
CO2
Nitrite & Nitrate
Mt. Kisco Sewage Disposal Plant
Weekly Analyses Sand Filter Effluent
1915
TURBIDITY
FREE CARBONIC ACID

DIAGRAM 2

The turbidity and sum of free ammonia and organic nitrogen are plotted from the base line and the carbonic acid and sum of nitrite and nitrate from the top on an inverted scale. In a general way the lines conform. It will be noted that inferior results occurred in January and in April, May and June.

It is only by constant attention that satisfactory results are obtained coupled with the supreme help of chlorination. There is also the tremendous dilution of the purified effluents. While the average figures for the year for the entire plant show an excellent purification, nevertheless, the safety of our water supply must rely upon eternal vigilance.

DISCUSSION

Mr. Paul Hansen: The speaker was very much interested in this paper, both because of the unique character of the plant and because of some of the rather unusual results that were obtained in its operation. It would be very enlightening to have a statement of the rates of application of sewage that are used on the filters, and also to know how the unusually high efficiency of the septic tank is obtained.

Mr. Theodore DeLong Coffin: As to the rates in the various parts of the plant, one of the charts which Dr. Hale showed gives the average time that the sewage is in contact within the various parts of the plant. That is not true for any specific time necessarily, because we have a great deal of ground water to contend with.

Mr. Paul Hansen: What is the population of the town?

Mr. Theodore DeLong Coffin: Three thousand people.

Mr. Paul Hansen: How would you express it in gallons per acre?

Mr. Theodore DeLong Coffin: The sand filters will care for 6000 people to the acre. The average flow of the sewage is not far from one third of a million gallons per day. At times it is as low as 200,000 gallons, and at times three times that quantity, or over half a million gallons.

Mr. John H. Gregory: What is the size of the screens?

Mr. Theodore DeLong Coffin: There are $1\frac{1}{2}$ inch bar screens and $\frac{3}{8}$ inch bar screens.

Mr. John H. Gregory: Is there any grit chamber?

Mr. Theodore DeLong Coffin: A small one.

Mr. John H. Gregory: Is it found necessary to use the auxiliary gasoline pump, or can reliable operation be obtained with the electrically operated pumps?

Mr. Theodore DeLong Coffin: It cannot be operated at all times of the year with the electrical operating pumps. Part of the trouble is produced by storms in the summer. The current is interrupted, and then the gasoline engine and pump are resorted to. At other seasons of the year, that is, early in the spring, there are great quantities of ground water which are in excess of the capacity of the electrical pumps, even though the quantity of the sewage running out is not in excess of the capacity of those pumps. After it rains continuously for some time, the electric pumps, on account of their very small water way and high efficiency, clog up, and the gasoline pumps are used; at other times one of the electrically operated pumps is out of service, for repairs, when necessarily the gasoline pump is put in service.

Mr. John H. Gregory: How frequently is it necessary to clean the pumps?

Mr. Theodore DeLong Coffin: About twice per month.

Mr. John H. Gregory: The septic tank is divided into compartments, is it not?

Mr. Theodore DeLong Coffin: Yes, two compartments.

Mr. John H. Gregory: Is one compartment allowed to stand after the sludge has accumulated?

MR. THEODORE DELONG COFFIN: Usually for about six months. The tank is operated for six months, and then there is a lapse of about six months before it is put into service again. In the meantime it stands full of sludge.

MR. JOHN H. GREGORY: Is the electric current purchased by the City of New York or does the city produce it?

MR. THEODORE DELONG COFFIN: It is purchased.

MR. C.-E. A. WINSLOW: What is the comparative bacteriological condition of the effluent and of the stream into which it flows?

MR. FRANK E. HALE: It is much better than the stream into which it flows.

MR. C.-E. A. WINSLOW: Is that uniformly the case?

MR. FRANK E. HALE: Yes.

PROF. R. L. SACKETT: The plant described presents very interesting features, and in very unusual combinations. The description of the plant and the analysis of the effluent raise in the minds of a number of us, very pertinent questions. On the charts showing the analyses, the tank treatment showed up very well in all its features; then came the contact beds, in which there seemed comparatively little advantage. The filters themselves produce a satisfactory service, and the sedimentation and then the chlorination apparatus; but one naturally asks, would not screening first, then tank treatment, and comparatively thorough filtration, followed by tank treatment and chlorination give equally good results, and with greater simplification? To be sure, it must be realized that this plant has unusual attention. In this country a considerable number of plants of equal size do not have this same expert and continuous attention. The point is directed more to the advantage of simplicity of parts. It would seem that under other circumstances, at least, some simplification in the plant would lead to as good results, at a less expenditure, and to simplification of operation. The filters were cultivated to some depth, and the result was that the organic matter which had accumulated on the surface was cul-

tivated down to a point below the surface, and covered over; that will lead to a condition there of stagnation of organic matter, and is calculated to fill up the pores of the filter with more material than it otherwise would. Experience has shown that the surface should not be disturbed to any considerable depth, thus putting the filter out of operation the shortest possible time, and permitting the very easy removal of the organic matter which collects on the surface, and that no considerable amount of the surface needs to be disturbed at all.

Mr. John R. Downes: The speaker thinks it a mistake to conclude that the beds do little good, or have little good effect. The work of the septic tanks and primary beds is simply preparatory to the work which is to be done by the final beds; at Plainfield, New Jersey, there are plain settling tanks and primary and secondary filter or contact beds, and while the primary beds do not produce any marked change, discernible in chemical terms, they do a valuable service in preparing the sewage for the final treatment. Certainly sand filters would not accomplish the work that they do, were it not for the preparatory effect of the contact beds. Each step in the process should be considered as simply preparatory to the next step and the treatment in the final bed as a preparation for the final dilution in the stream. By making "Dissolved Oxygen Consumed" tests you will be able to interpret into chemical terms a part, at least, of the preparatory effect of each step which can be shown in no other way.

In a paper before the New Jersey Sewage Works Association the speaker described an experiment comparing the mechanical aeration of (a) tank effluent, (b) primary effluent, and (c) tank effluent to which dirty cinders from the secondary beds were added. The effect of the retained "activator" in the primary effluent was very clearly shown, as was that of the "activator" supplied from the cinders in the third case.

Mr. M. N. Baker: What did New York City help pay for? Did it help pay for the sewerage system in the village, the trunk sewers and the disposal works, or only the disposal works, and how was that cost divided, that is, what proportion did the village pay and what proportion did the city pay; and also how was the cost of the operation divided between the city and the village? Who

constructed the plant—did New York City design and construct the plant; and who operates the plant, the village or New York City?

MR. THEODORE DELONG COFFIN: The agreement provided that the village should deliver all the sewage of the village to the pumping station, and the village has built the sewers to the pumping station. At the pumping station the plants of the city of New York begin; there the expense to the city begins. It built the pumping station and the disposal plant; it operates the pumping station and the disposal plant; and the village operates its sewer line to the pumping station.

DR. D. P. CURRY: What is the cost of this plant, the per capita cost, for installation and operation?

MR. THEODORE DELONG COFFIN: The plant cost $70,000 in round figures. The population is 3000.

DR. D. P. CURRY: Does that include the pumping station or simply the sewage disposal plant proper?

MR. THEODORE DELONG COFFIN: The pumping station and disposal works.

MR. FRANK E. HALE: The speaker would like to make one statement in regard to the contact beds. It was not his intention to give the impression that the contact beds were doing as efficient work as contact beds should do. Apparently they are not operating correctly. The highest efficiency is not claimed for them, but they are accomplishing a certain amount of necessary work; they were installed in order to avoid a nuisance; there is no doubt that trickling filters or other methods might produce a greater efficiency, but we have the minimum nuisance. The contact beds work over material, so that, after it leaves them, the purification still goes on in the settling basin. In the light of experience, improvement can be made.

DR. D. P. CURRY: You are contending with conditions peculiar to that particular section?

Mr. Theodore DeLong Coffin: Yes.

Mr. C. A. Haskins: How is chlorine added to the effluent in the sand filter, and how long a period of contact is allowed, and how far below that point are samples collected? The figures given by Dr. Hale seem rather high.

Mr. Theodore DeLong Coffin: The rate of the application of the chlorine is on the average as Doctor Hale gave it; but there is a variation in the application, due to the fact that the filters are not filtering continuously; they receive their charges of sewage as the contact beds empty. Therefore the rate is very variable. In order to "dose" the maximum flow an excess quantity of chlorine is used, which brings the average high. The chlorine is run as a solution into the man-hole through which all the effluent from the plant is passed, and from this man-hole the effluent is run out into a tank which is perhaps thirty feet long and twenty feet wide, the treated effluent circulating through the tank, and discharging directly into the river. There is at no time more than half an hour elapsing between the time of applying the chlorine and the time the chlorinated effluent reaches the stream. A sample of the chlorinated effluent is picked up as the effluent reaches the river.

TESTS FOR BACILLUS COLI AS AN INDICATOR OF WATER POLLUTION

By C.-E. A. Winslow

For nearly twenty-five years the number of colon bacilli present in water has been used as a test of its sanitary quality. The writer does not know who originally devised this test; but the first instance of its use with which he is familiar in this country is the study by Theobald Smith of certain New York river waters in 1893.[1]

The value of the colon test has been more and more generally recognized in this country and in England. In Germany there has always been a strong school which has been doubtful of its significance, but the more important recent papers, such as that of Quantz,[2] recognize the value of the colon test if intelligently applied. The German investigators have performed a valuable service in emphasizing the fact that the number of colon bacilli present in a water is only one link in a chain of circumstantial evidence of which the sanitary inspection forms an essential and integral part. The writer is also wholly in accord with their contention that the 20° gelatin count is a test which is often of the greatest assistance in forming judgment of the quality of a water, having in mind for example the case of the water supply of Auburn, New York, Lake Owasco. In this lake, according to the exhaustive data collected by Mr. J. W. Ackerman the gelatin count rises sharply each year at the time of the spring thaw, while colon bacilli, never very abundant, are more numerous during the summer.

The explanation of this phenomenon probably is that a certain proportion of colon bacilli are always contributed by the small brooks which enter the lake from agricultural land, which, not being of human origin, have but little significance. At the time of the spring thaws, which for the most part wash an open farming country, the normal contribution of *B. coli* from the fields is obscured by the rain and melting snow, while only the rise in total count

[1] Thirteenth Ann. Rep. State Bd. Health of N. Y. for 1892, p. 712.

[2] *Zeit. f. Hyg.*, 1914, vol. lxxviii, p. 193.

registers the fact that contaminating material of all sorts is being washed into the lake. With this contaminating material, for the most part of a harmless nature, human excreta is washed in from certain points on the watershed, and in the spring of 1908 the excreta contained specific typhoid infection and an epidemic in Auburn was the result. In this case then the total count of bacteria was a more accurate index of danger than the colon content. Fully granting, however, the importance of sanitary inspection and the value of the gelatin count it remains true that the colon test is one of the most valuable diagnostic instruments at the disposal of the sanitarian.

There can be no doubt that colon bacilli are typical inhabitants of the intestine of man and other warm blooded animals; that these intestinal colon bacilli tend to die out rather rapidly in water; and that they are not found in very large numbers in any natural waters not subject to considerable pollution from sewage or recent wash from the surface of the soil. The writer sees no reason to modify the conclusion of Professor Prescott and himself that:

> Altogether the evidence is quite conclusive that the absence of *B. coli* demonstrates the harmlessness of a water as far as bacteriology can prove it. That when present, its members form a reasonably close index of the amount of pollution, the authors above quoted have proved beyond reasonable cavil. It may safely be said that when the colon bacillus is found in such abundance as to be isolated in a large proportion of cases from 1 cc. of water, it is generally proof of the presence of serious pollution.

The colon group may be broadly defined as including all aerobic non-spore-forming bacilli which produce acid and gas in glucose and lactose media. This is a large and complex group, and it is of great importance to determine whether all of its members are equally significant, or whether there are special types which are more intimately associated with the intestines of warm blooded animals and hence of special importance from a sanitary standpoint. The group as a whole is not present in very large numbers in pure waters, but in order to obtain results of any precision it is important to define the intestinal *B. coli* if possible more closely.

Bacteriologists in the laboratories of the Massachusetts State Board of Health[3] and the Massachusetts Institute of Technology long ago attacked this problem and their conclusions were embodied

[3] Thirtieth Ann. Rep. State Bd. Health of Mass. for 1898, p. 533.

in the 1905 Report of the Committee on Standard Methods of Water Analysis of the American Public Health Association.[4] The identification of the colon group involved the determination of typical morphology, motility, fermentation of glucose broth, coagulation of milk, production of indol and reduction of nitrates, all under definitely standardized conditions.

These tests were pretty generally adopted in this country for the next five years after the committee on standard methods made its report. Gradually, however, practical laboratory men became restive under the exactions of this procedure. The complete test required the use of seven different media and took nine days to complete. Furthermore there was no definite evidence that the tests used were really calculated to distinguish between fresh fecal colon bacilli and others, the only adequate basis for such a time-consuming and troublesome procedure. There is to-day not the slightest reason to suppose that motility and nitrate reduction at least have any important significance of this kind.

When therefore Whipple[5] suggested the use of a single "presumptive test" gas production in glucose broth, and particularly when Jackson[6] introduced the new test of gas production in lactose bile, they received a ready hearing among bacteriologists. It was known that lactose bile would inhibit a certain number of sensitive strains of *B. coli*, particularly in waters of fairly good quality, while on the other hand it was recognized that other organisms than colon bacilli, particularly anaerobic spore formers, would at times give fallacious positive results. It was shown, however, that in a number of waters studied this error was not a large one, and since the colon test can only be interpreted broadly in any case it was generally believed that the slightly greater accuracy of the older isolation tests scarcely compensated for the trouble involved. The laboratory section of the American Public Health Association, at its Washington meeting, in September 1912, adopted a resolution recommending determinations of counts at 20° and 37°, and the lactose bile presumptive test as the standard routine procedure in water examinations.

Experience obtained during the past two years has, however,

[4] *Jour. Infect. Dis.*, 1905, Supp. No. 1, p. 1.

[5] Tech. Quart., 1903, vol. xvi, p. 18.

[6] Biological Studies by the pupils of William Thompson Sedgwick, 1906; also *Jour. Inf. Dis.*, 1907, Supp. No. 3, p. 30.

tended to emphasize the importance of the error involved in the assumption that gas formation in lactose bile is even a rough index of the presence of bacilli of the colon group. It appears that, while a large percentage of random bile tests on waters of various origin may prove to be colon bacilli, certain waters, and particularly those of rather good quality, may consistently give the bile presumptive test without colon bacilli being present at all. George W. Fuller[7] has recently pointed out a number of instances of this kind. The water supply of Cincinnati, for example, when drawn from a highly polluted part of the river showed colon bacilli, as determined by confirmatory tests, in 60 per cent of 1 cc. samples, while at the present intake seven miles above and in a vastly better location it shows positive presumptive tests in 85 to 90 per cent of the samples tested. In New Orleans complete confirmatory tests used to show colon bacilli only 3 per cent of the time when from 100 to 300 cc. of water were tested, while presumptive tests in 1 cc. are positive in 80 per cent of the samples tested now. At Columbus, Ohio, Grand Rapids, Michigan, and Evanston, Illinois, Fuller cites cases of well filtered and almost sterile waters giving positive presumptive tests.

The International Joint Commission on the Pollution of Boundary Waters presented striking evidence along this line cited in Table 1.

The most exhaustive investigation of this point is the admirable study of the Potomac River by Hugh S. Cumming of the United States Public Health Service.[8] The principal results of this study, so far as they bear on the presumptive test are cited in Table 2.

It is evident from this table that in the upper reaches of the river where colon bacilli were present to the number of 100 or more per cubic centimeter the majority of the gas formers were *B. coli*. At Maryland Point, however, and below, where the pollution was much less, one to two-thirds of the gas formers present were not colon bacilli at all. Anaerobic spore forming bacilli of the *B. Welchii* or *B. sporogenes* type were isolated from the tubes which gave gas but no *B. coli*, and a special study by inoculating fermentation tubes at 70° F. showed that these gas forming anaerobes were quite constantly present in numbers varying from 1 to 50 per 10 cc. of water.

In a recent series of examinations of water from the five different sources which supply the city of New Haven, a considerable percent-

[7] *Jour. Franklin Inst.*, 1915, vol. clxxx, p. 17.
[8] Bull. 104 U. S. Hyg. Lab., 1916.

age of the samples showed gas formers, with no colon bacilli present, the positive gas tubes failing to show any fermenting organisms at all when plated out on lactose agar plates.

TABLE 1

Gas producers, St. Johns River

(International Joint Commission on the Pollution of Boundary Water)

SAMPLING POINT	NUMBER OF SAMPLES TAKEN	AVERAGE PER 100 CC. BY PHELPS METHOD		
		Total gas producers	Typical B. coli	Anaerobic gas producers
1	21	467	65	402
2	21	647	160	487
3	21	566	70	496
4	20	472	167	305
5	21	536	160	376
6	21	643	112	531
7	21	515	155	360
8	21	730	250	480
9	21	433	18	415
10	21	433	112	321
11	21	519	57	462
12	21	600	61	539
13	21	519	74	445
14	21	561	103	458
15	21	566	164	402
16	21	604	155	449
17	21	476	31	445
18	21	480	117	363
19	21	467	117	350
20	21	600	155	445
21	21	520	103	417
22	21	566	112	454
23	21	1,086	725	361
24	21	695	202	493
25	21	614	112	502
26	21	601	117	484
27	21	524	57	467
28	20	540	254	286
29	21	1,090	631	359
30	20	476	112	364
31	21	480	112	364
32	21	528	70	458

With disinfected waters the error due to the presence of the anaerobic spore bearers is of course particularly serious, as noted by Wells at Grand Forks, North Dakota, by Palmer at Trenton, New

TABLE 2

Gas-forming organisms from various stations confirmed or not as being B. coli

(Potomac River, Hugh S. Cumming)

CROSS SECTIONS	NUMBER OF SAMPLES	AVERAGE NUMBER OF B. COLI PER CC.	AVERAGE NUMBER OF GAS FORMERS NOT B. COLI PER CC.	B. COLI, PERCENTAGE OF TOTAL GAS FORMERS
Giesboro Point	770	295.0	24.1	92.4
Fort Foote	789	254.0	9.7	96.3
Fort Washington	778	123.0	6.2	95.2
Mount Vernon to Whitestone Point	851	102.0	8.5	92.3
Indianhead	241	123.0	15.7	88.6
Possum Point	212	66.2	13.8	82.7
Maryland Point	691	1.44	0.75	65.7
Popes Creek	740	0.19	0.33	36.5
Lower Cedar Point	476	0.14	0.16	46.6
Below Lower Cedar Point	2,261	0.052	0.057	47.5

Jersey and others. Altogether Dr. Cumming is certainly right in his conclusion that:

> The reliability of the lactose-broth and lactose-bile presumptive test varies directly with the degree of pollution, therefore inversely with the remoteness in time and distance from the source of pollution. This is due to the general occurrence of a group of organisms in small and almost constant numbers, approximating 1 per cc., which are not manifest when the number of *B. coli* is large, but appear evident when the number of *B. coli* approaches or is less than 1 per cc.

The presumptive test must then certainly be abandoned except for waters of very bad quality, or at least supplemented by confirmatory plating to show the presence of the aerobic non-spore forming colon group.

Granting that such confirmatory tests must be made, the question is still open whether lactose bile shall still be used for preliminary enrichment of the sample, or whether lactose broth or some other medium may not be preferable if the idea of a single presumptive test is to be abandoned. It has been generally acknowledged that the use of lactose broth followed by confirmatory tests would give a larger number of positive results than the use of lactose bile followed by confirmatory tests, since bile inhibits a certain proportion of organisms of the colon group. The only real advantage lay in its usefulness as a single presumptive test because of the fact that lac-

tose broth gives much too high results if used as a presumptive test alone. Thus Stokes and Stoner[9] found that of cultures isolated from tubes showing gas formation in lactose broth and lactose bile 88 per cent and 95 per cent respectively proved to be *B. coli;* so Cumming reports 70 per cent of positive broth tubes and 87 per cent of positive bile tubes confirmed in the Potomac River. If confirmatory tests are to be made, however, they will take care of any errors due to the formation of gas by organisms other than *B. coli,* while the absolutely higher results obtained with lactose broth offer a very important advantage. Thus in Dr. Cummings' study of the Potomac River, to which reference has been made, the total number of colon bacilli per cubic centimeter as determined by lactose broth followed by confirmatory tests was 84 against 47 for lactose bile followed by confirmatory tests. M. M. Obst[10] has recently compared lactose bile and lactose broth as preliminary enrichment media, coming to the same conclusion, that bile inhibits about half the colon bacilli which may be obtained by the use of lactose broth. Mrs. Obst also emphasizes the costly and laborious procedure often involved in obtaining the bile medium.

Altogether it may be concluded that the method of testing for the colon group which has been adopted by the United States Hygienic Laboratory probably represents the best present practice, a practice which the writer personally hopes will be adopted by the Committee of the American Public Health Association on Standard Methods for the Bacteriological Examination of Water when it finally makes its long-expected report. The essential points in this method are (a) preliminary enrichment of the sample to be tested in lactose pepton broth for 48 hours at 37°C.; (b) plating on Endo medium or lactose litmus agar from all samples showing gas after 24 hours and again after 48 hours from those tubes which have become positive after being negative the first time; (c) in case plates are doubtful fishing from suspicious colonies to a confirmatory fermentation tube of lactose broth, which if positive should show 10 per cent or more of gas after 48 hours at 37°.

Accepting this test as a simple and accurate method of determining the presence of bacilli of the colon group taken as a whole there still remains the important question whether any further tests can, with advantage, be used to distinguish special types within the group

[9] *Amer. Jour. Pub. Hyg.*, vol. xix, 1909, p. 312.
[10] *Jour. Bact.*, vol. 1, 1916, p. 73.

which may be of particular importance as indicators of recent fecal pollution.

Many observers, both in this country and in England, have pointed out that in recently polluted waters the bacilli of the colon group are apt to be of a more vigorous type, fermenting sugars and producing indol in a higher percentage of cases. Thus Houston[11] showed that 53 per cent of the strains isolated from raw river waters were "typical" in fermenting lactose and forming indol against only 34 per cent of the strains found in stored and filtered waters. The most marked differences appeared in the fermentation of saccharose and raffinose and the production of indol.

In the attempt to classify bacilli of the colon group by their fermentative reactions saccharose has usually been considered as of primary importance. All of the members of the group of course ferment glucose and lactose, but as pointed out by Theobald Smith[12] saccharose fermentation divides the series into two more or less distinct types. MacConkey[13] followed by Jackson[14] and the Committee on Standard Methods have further subdivided the positive and negative saccharose groups according to the fermentation of dulcite. The table below indicates the general characters of the four types of the colon group as they have most commonly been defined.

TABLE 3

FERMENTATION OF		TYPE
Saccharose	Dulcite	
+	−	B. aerogenes
+	+	B. communior
−	+	B. communis
−	−	B. acidi-lactici

Kligler[15] believes from his studies that salicin fermentation is more closely correlated with other characters than is the fermentation of dulcite. He distinguishes *B. aerogenes* from *B. communior* by positive fermentation of salicin rather than negative fermentation

[11] Seventh Report on Research Work, Metropolitan Water Board, London, 1911.

[12] The Wilder Quarter-Century Book, 1893, p. 187.

[13] *Jour. Hyg.*, vol. v, 1905, p. 333; also *Jour. Hyg.*, vol. vi, 1906, p. 385.

[14] *Jour. of the Am. Pub. Health Assn.*, vol. i, p. 930.

[15] *Jour. Inf. Dis.*, 1914, vol. xv, p. 187.

of dulcite, and *B. acidi-lactici* from *B. communis* by negative fermentation of salicin rather than negative fermentation of dulcite.

The difficulty inherent in such classifications as the above is that they are in large measure arbitrary. One can make an almost endless number of divisions by using different fermentable substances, and they cross each other in the most confusing manner. Furthermore the attempt to show any constant relation between the MacConkey types and the quality of the water in which they occur has not proved successful. Clemesha[16] found in a study of surface waters in India that bacilli of the *B. communis* and *B. communior* (dulcite positive) types were associated with fresh pollution, while those allied to *B. acidi-lactici* and *B. aerogenes* were more persistent in stored waters; but Houston[17] in England failed to confirm these conclusions. Two years ago it seemed that the attempt to work out a classification of the colon group which would be of practical sanitary value was almost hopeless.

A very interesting discovery of Harden and Walpole's[18] has recently been developed by Rogers, Clark and Davis of the United States Bureau of Animal Industry[19] into the most important step taken for twenty years in the classification of the colon group. These observers find that the fermentation of glucose by bacteria of the colon series may follow two entirely different lines, leading in one case to the production of gas which when collected under a vacuum is composed of about equal parts of carbon dioxid and hydrogen, while in the other case the ratio of carbon dioxid to hydrogen is in the ratio of 2 to 1. The second or high ratio group is usually saccharose-positive and dulcite-negative, corresponding to the older definition of *B. aerogenes*.

As long as the differentiation of this peculiar high-ratio type depended on gas analysis conducted in a vacuum it was of little practical importance as a basis for routine procedure. Clark and Lubs,[20] however, have correlated the high ratio type of fermentation with

[16] The Bacteriology of Surface Waters in the Tropics, Calcutta, 1912.

[17] Seventh Report on Research Work, Metropolitan Water Board, London, 1911.

[18] *Jour. of Hyg.*, 1905, vol. v, p. 488; also *Proc. Roy. Soc.* (B), 1905–1906, vol. lxxvii, p. 399.

[19] *Jour. Infect. Dis.*, 1914, vol. xiv, p. 411; also *Jour. Infect. Dis.*, 1914, vol. xv, p. 100.

[20] *Jour. Infect. Dis.*, 1915, vol. xvii, p. 160; also *Jour. of Biol. Chem.*, 1915, vol. xxii, p. 87.

the hydrogen ion concentration in glucose broth and have thus given us a simple and reliable practical test for its recognition.

Rogers, Clark and Lubs have also performed a service of capital importance in calling attention to the serious errors involved in the ordinary methods of titrating media by adding strong acid or alkali to bring the reaction to a definite point. The true hydrogen ion concentration can be determined only by the use of the potentiometer or by the application of a graded series of indicators such as have been worked out by Lubs and Clark.[21] The use of these methods shows a striking difference between the colon and the aerogenes types as indicated by the table below from results recently obtained by the colorimetric method in the writer's laboratory at the Yale Medical School.

Rogers and his associates pointed out that the high-ratio, low-hydrogen-ion aerogenes strains are usually saccharose-positive, raffinose-positive, and dulcite-negative, and very often indol-negative, and that among them are to be found representatives of the liquefying or *B. cloacae* type. Winslow and Kligler[22] have specially emphasized the negative indol reaction of *B. aerogenes.* Levine[23] following Harden and Walpole,[23] Harden[24] and Harden and Norris,[25] has shown that a positive Voges-Proskauer reaction is also characteristic of this type.

The most important point, however, from a practical sanitary standpoint is the origin in nature of these two sub-types of the colon group. It was the discovery by Rogers, Clark and Evans[26] of a distinct difference in habitat that made the differentiation of *B. coli* from *B. aerogenes* of capital significance.

Rogers and his associates showed that the true *B. coli* is characteristic of bovine feces while the *B. aerogenes* type is the characteristic form found on grains. Of 150 strains from bovine feces only one was of the high ratio type against 151 out of 166 grain cultures.

[21] *Jour. Wash. Acad. Sci.*, 1915, vol. v, p. 609; also *Jour. of Infect. Dis.*, 1915, vol. xvii, p. 109.

[22] *Jour. of Bact.*, 1916, vol. i, p. 81.

[23] *Proc. Roy. Soc.* (B), 1905–1906, vol. lxxvii, p. 399.

[24] *Proc. Roy. Soc.*, 1905–1906, vol. lxxvii, p. 424.

[25] *Proc. Roy. Soc.* (B), 1911–1912, vol. lxxxiv, p. 492; also *Proc. Roy. Soc.*, 1912, vol. lxxxv, p. 73; also *Jour. of Physiol.*, 1911, vol. xlvii, p. 332.

[26] *Jour. of Infect. Dis.*, 1914, vol. xv, p. 100; also *Jour. of Infect. Dis.*, 1915, vol. xvii, p. 137.

More recently Rogers, Clark and Lubs[27] have reported that 107 out of 113 human fecal strains were of the low ratio type. Rogers[28] found in a study of 137 cultures isolated from water that the *B. coli* type was found occasionally in springs in which there was no

TABLE 4

Hydrogen ion concentration produced by B. coli and B. aerogenes in glucose pepton broth

CULTURE	B. COLI P_H^+ VALUE AFTER						
	2 hours	4 hours	8 hours	1 day	2 days	4 days	7 days
17	7.3	7.2	6.1	4.8	4.7	4.5	4.6
19	7.2	6.8	5.6	4.8	4.7	4.5	4.8
44	7.3	7.2	6.2+	4.8	4.8	4.8	5.0
45	7.0	7.0	6.0	4.8	4.8	4.5	4.6
47	7.3	7.2	6.2+	5.0	5.0	4.4	4.8
52	7.3	7.0	6.0	4.8	4.3	4.5	4.5
78	7.2	7.2	6.1	4.8	5.0	5.0	4.9
95	7.3	7.1	6.0	4.7	4.8	4.6	4.5
104	7.2	7.0	6.1	4.7	4.3	4.4	4.8
125	7.1	7.1	6.0	4.8	4.3	4.7	4.6

CULTURE	B. AEROGENES P_H^+ VALUE AFTER						
	2 hours	4 hours	8 hours	1 day	2 days	4 days	7 days
23	7.3	7.2	6.0	5.8	6.2	7.2	7.2
24	7.2	6.9	5.6	5.5	6.2	7.2	7.1
123	7.3	7.1	5.8	5.7	6.2	6.6	6.8
136	7.2	6.6	6.0	5.7	7.0	7.2	7.2
233	7.3	7.2	6.2+	5.8	6.2	7.2	7.2
240	7.2	7.2	5.6	5.6	6.6	6.5	6.6
369	7.2	7.0	5.6	6.0	6.6	7.0	6.8
454	7.3	7.2	6.2+	5.1	6.0	6.4	7.1
529	7.2	6.8	5.5	5.8	6.6	6.5	6.4
583	7.3	7.2	5.8	5.7	6.9	7.2	7.2

evident source of contamination but was especially abundant in sewage polluted rivers, while the *B. aerogenes* type was found in waters of all sorts. Johnson[29] reports that of 363 colon group

[27] *Jour. of Bact.*, 1916, vol. i, p. 82.
[28] *Jour. of Bact.*, 1916, vol. i, p. 82.
[29] *Jour. of Bact.*, 1916, vol. i, p. 96.

organisms from soil, 261 were of the *B. aerogenes* type and of these 219 gave the Voges-Proskauer reaction.

The general correlation of the two different types of carbohydrate fermentation with indol fermentation, saccharose fermentatation, dulcite fermentation and the Voges-Proskauer reaction appear to explain many of the results obtained by MacConkey, Houston and Clemesha in regard to the special significance of "typical" *B. coli*. Since, however, there are bacilli of the *B. coli* fermentative type which ferment saccharose and fail to ferment dulcite and some of the *B. aerogenes* type which form indol the results of these earlier observers were conflicting and unsatisfactory. The radical difference in fermentative power is evidently the most fundamental of all the lines of demarcation within the colon group, and a study of this reaction promises to be of great value in sanitary water analysis.

The simplest differential test for the two types is the hydrogen ion concentration in glucose pepton broth. The exact concentration will of course vary with the composition of the medium and the time and temperature of incubation. In the writer's own work he has used a broth made up with 0.5 per cent glucose, 0.5 K_2HPO_4 and 1.0 per cent Witte's Pepton. Clark and Lubs[30] recommend 0.5 per cent pepton instead of 1.0 per cent. The cultures were incubated in the writer's studies at 30° but he sees no reason why a 37° incubation should not be equally satisfactory for routine sanitary purposes. At the end of 48 hours the cultures should be tested by the addition of a few drops of a methyl red solution (0.1 gram methyl red dissolved in 300 cc. alcohol, and diluted to 500 cc. with distilled water). At a hydrogen ion concentration of about 5.8 $\left(P_{H}^{+} \text{ value}\right)$ methyl red changes from red to yellow so that, as may be inferred from the data cited on in Table 4, the *B. coli* type will show a brilliant red coloration while the *B. aerogenes* cultures will be yellow.

Only extensive studies of the distribution of bacteria of these two types in waters of different quality and a correlation of the results with those of sanitary inspection will give us a safe basis for an interpretation of the respective significance of the *B. aerogenes* and *B. coli* types. The errors which we have all made in the application of the colon test in the past should be a warning against hasty

[30] *Jour. of Infect. Dis.*, 1915, vol. xvii, p. 160.

generalization. Yet the results already obtained are sufficiently promising to suggest that we have at last perhaps a test which may really differentiate fecal colon bacilli from related types found in soil and on grains and grasses. The writer trusts that the bacteriologists in water works laboratories will take advantage of their unusual opportunities for accumulating data in regard to this point by applying the simple methyl red test outlined above to subcultures from confirmatory Endo or lactose agar plates in as large a proportion of colon isolations as possible. We know today that the whole group of aerobic gas formers, *B. coli* and *B. aerogenes* alike, are not found in large numbers in waters of high quality; but if *B. coli* proves indeed to be a purely fecal form and *B. aerogenes* a saprophyte the precision of our tests will be greatly increased and an accurate interpretation vastly simplified.

DISCUSSION

Dr. W. P. Mason: As set forth in the title of this paper it deals with an indicator of water pollution. From a bacteriological standpoint all that Professor Winslow has had to say is doubtless very complete and very well done, and we are of necessity under obligations to him; but from a practical standpoint the speaker would hardly like to throw overboard the old presumptive test, and tie up to anything very new until that new procedure has been pretty thoroughly thrashed out; in dealing with water matters he likes to get all types of facts before him, bacteriological, chemical and, above all, the sanitary survey. Now, a word with reference to something that happened the day before yesterday. The speaker was asked to look into and pass upon a question of damage to a deep well, a well having a depth of over 100 feet, and he sent a trustworthy member of his staff to take a sample and make a sanitary survey. The sample was taken and the sanitary survey reported as excellent. The house was on the top of a ridge, and the well was 100 feet deep, drilled in shale rock. The house was sewered, with delivery to a cesspool, and the cesspool to which the sewer ran was a long distance away. There were no barns nearby but there was a garage. In making an examination of the water by the presumptive test gas was found to a slight extent, one tube in ten. However, the chlorine ran high; so did the nitrates and there were

some nitrites as well. The man who took the sample was interrogated and nothing was found the matter with his sanitary survey. On a personal investigation the premises were found as reported, but, closer inspection disclosed behind the garage a very small privy, described by the owner as "nothing in particular," adding that "it had not been used for a long time." However, it had been used, probably inside of half a day. It had been in regular use about once a day, by probably one person only, and it was within ten feet of the mouth of the well. This is but another instance showing how valuable it is to secure all forms of information bearing upon the case when asked to pass judgment upon the quality of a water—laboratory data alone may be misleading, not with any desire to belittle the value of bacteriological or chemical examinations. We want all the light that can be given but if but one form of information is available, the speaker would rather have the sanitary survey than all the rest of them put together. No result of bacteriological examination, or chemical results should be taken as material; the sanitary survey is enough. Nor should it be questioned whether the party using the privy happens to be capable of giving a disease so far as the result on the worth in the water is concerned. To repeat, it is better not to tie up to any one particular test, but to make a bacteriological and a chemical examination, to take both into consideration, and to put the sanitary survey above them all.

Dr. Frank E. Hale: The speaker has been very much interested in Mr. Winslow's paper, particularly the question of methods, and cannot help making a few remarks upon three points brought up by Mr. Winslow. In the first place, as to the classification of *B. coli*, the speaker cannot agree with Mr. Winslow that the present classification of standard methods is not a useful one. That classification is a real classification and is useful in distinguishing varieties that are real and distinctive. All the forms are of fecal origin, many originally were isolated from diseased conditions. Vaccine made from them cured the conditions when the specific form had been isolated. A classification which enables one to do this cannot be said to have outgrown its usefulness. Again all of the varieties were kept for years and retained their original characteristics. The proposed classification is on broader lines and less specific in detail. It merely divides into groups those now contained in the present classification, and could not possibly show a wide adapta-

bility. To introduce into routine work additional tests to the presumptive test, so as to limit significance to certain groups of the present classification, is an entirely different and separate question, and offers no argument for discarding the present classification.

No advance will be made until we are able to distinguish between animal and human *B. coli* varieties, if that ever be possible. Croton water has shown tests for *B. coli* in 0.1 cc. daily for a month, when inspection disclosed no probability of human pollution. The direct test for *B. typhii* from the bile tubes then becomes important.

In the second place, as to the use of lactose bile versus lactose broth, even if the presumptive test is not alone relied upon, lactose broth was found wanting long before bile was discovered. Why should we now go backward? Since the Committee on the Revision of Standard Methods has advocated the use of lactose broth we have again made at Mt. Prospect Laboratory a series of comparisons with the lactose bile and lactose broth, confirming by litmus lactose agar. The broth was made as recommended by the committee; the bile was 5 per cent as recently recommended from this laboratory. The results were all in favor of bile, quicker gas formation, gas in larger amounts, and less *B. Welchii* forms. In one day the results with bile were practically equal to those obtained in two days with the broth. Very few bile tubes show less than 10 per cent of gas, whereas many broth tubes show small amounts of gas, and the larger amounts of gas in the broth were produced by *B. Welchii* forms. It is not safe to trust small amounts of gas, since such may be due to inversion of lactose to dextrose in sterilizing. Possibly it would be well to lower the presumptive requirements with lactose bile to plus 10 per cent gas and make corroborative tests when conditions call for it. This would retain the presumptive test where permissible and allow of direct test for *B. typhii* from the bile tube on Hesse or other media. Most previous comparative work has been with 10 per cent bile, and frequently improper bile has been used. Desiccated bile of the right quality may now be obtained.

In the third place, as to *B. Welchii* forms, the speaker believes they are of direct sanitary significance. They are associated in large numbers with pernicious anaemia and dozens of other diseases. The speaker does not believe the percentage of these forms in the presumptive bile test is commonly as high as has recently been stated. Creel was dealing with special conditions, tanks on

railroad trains where opportunity was excellent for accumulating spores. If the ordinary surface water contained a high percentage of *B. Welchii* spores chlorination could not show the percentage removal of *B. coli* by the presumptive test that is common experience. Removal of 90 per cent and more is not uncommon in New York City supplies, and this is probably not exceptional. It may be, however, that the introduction of chlorination has increased somewhat the percentage of *B. Welchii* forms found today over that of previous experience. This has been found to be true recently in comparing chlorinated with unchlorinated waters.

Mr. C.-E. A. Winslow: With reference to Dr. Hale's comparison of the lactose bile and the lactose broth tests, it may be that conditions are different in New York waters. We have taken our data from results obtained in various places; different laboratories in various parts of the country. Of course Dr. Hale's tests show the value of the presumptive test in New York waters, but it does not work out the same way in the case of other waters. The *B. Welchii* group for some reason is apparently not abundant in New York water; but it is very abundant in a great many other waters in different parts of the country. The speaker does not see why the confirmatory test should not be retained and used in places where the *B. Welchii* group is not abundant.

He cannot feel that soil washings and from manured fields are so negligible as Dr. Hale believes, and is inclined to take the stand that Dr. Mason did when he had the experience of finding the privy over the well. We have sufficient data from all over the country of serious disease caused by washings from the surface of the soil, to make us feel that no water supply is ever safe if exposed to such sources of contamination, whether they have sewers emptying into them or not. There are several cases in point where there was doubt as to the source of the colon bacilli, whether from privies or manure piles, or what not, but where the danger from an epidemic of typhoid was always present until the waters were chlorinated. The speaker is naturally in accord with what Dr. Mason said about the sanitary inspection. That is the most essential thing, one of the most essential means of determination of the source of contamination, but there are many cases where the sanitary inspection does not help; where the cause is obscure.

Dr. Frank E. Hale: It is certain, however, that we get better results with the bile test, and from our experience in New York we believe that it is surer.

Mr. Daniel D. Jackson: Unfortunately the speaker has not done any laboratory work along this line in the past three years, and has no new results in connection with it, aside from what has already been discussed and printed, but would like to add this word concerning the great value of sanitary inspection as related to analysis. He had occasion, only a short time ago, to examine a water supply which was very high in *B. coli,* and also in chlorides. This water supply had been condemned by the state, one of the southern states, without what the speaker considered an adequate examination as to sanitary conditions. Any examination into the condition, from the analysis alone, would have undoubtedly led anyone to condemn it. Sanitary inspection, however, showed that on one of the series of wells the chlorine was considerably beyond what would be found in any sewage. Therefore it did not come from the sewage. There was a natural salt pocket at one end of the well system, as these wells were on the edge of the coastal plane. By discontinuing half a dozen of the wells on one end of the line and carrying the well line to the other side, the wells could be relocated so as to contain the natural amount of salt.

Now, as to the *B. coli.* It was necessary to get up at four o'clock in the morning to find out where the *B. coli* came from, when, just as the sunrise began, was revealed some four or five turkey buzzards on top of the collecting or receiving chambers where the water was being pumped from each well by an air lift. The turkey buzzards were not particular which way they were facing. There was a collection of some 25 wells, and the receiving chamber of each gave tests for *B. coli* which were positive in 1 cc. This would ordinarily condemn them, but, by properly covering these receiving chambers, the coli content was reduced to zero. Now, it is not right to condemn a property without a proper sanitary inspection. It is quite right to report against it, but the source should be inspected to see if it can be fixed up rather than, as in this case, to condemn $200,000 worth of property.

Dr. W. P. Mason: A case entirely similar to that came under the speaker's observation. The turkey buzzards were not in evi-

dence but a flock of small birds were. It could not make any difference which way they turned, as they were so short. The deep well water which flowed into an open funnel like receiver caught the pollution.

Mr. Chester G. Wigley: The coli determination with lactose bile is a very valuable aid in the work of the state department of health, especially in field operations. Experience with it shows that it is the best self contained process that can be used in the field. For that reason the department has hesitated to stop the use of it altogether; that is, where a man is limited by the amount of material that he can carry and by his very small laboratory facilities, because in field work the opportunities for confirmation are not very good. The bile figures have given very valuable information fairly indicative of conditions found by sanitary surveys while the broth indications were not nearly as clear, or as satisfactory. There is another consideration in reference to the proposal of the new standard for coli determination, and that is the fact that it is unfortunate that just about the time we begin to get some fair understanding of one test a new process is proposed, the limitations of which have not yet been worked out. It may be that the test which Professor Winslow suggests would have certain advantages, if its use under particular or peculiar conditions were tested out so that it would not mean that we would run into more complications. In many ways its adoption would cause difficulties to some of us who work in the field, because it would mean that we would of necessity be compelled to carry along supplies for both methods, for the purposes of comparison, before we could feel perfectly safe in basing our opinions upon the result of new methods.

Mr. Mayo Tolman: The speaker has been especially interested in Professor Winslow's paper, as several years ago he made a study of the pollution of the Assabet River between the towns of Hudson and Concord, Massachusetts, and at that time, being curious to see how the species of colon bacilli found in polluted water would compare with those isolated from feces by MacConkey, Winslow, Walker and others, made a detailed study of quite a number of samples. For the purpose of determining the species of the colon bacillus present, a pure culture was isolated by the streak method, on blood serum from that tube of lactose bile of the greatest pollu-

tion, showing between 20 per cent and 80 per cent gas production. The fermenting power of this culture toward dextrose lactose, dulcite, saccharose, mannite and raffinose was determined, as was also the motility of the organism, reduction of nitrates, production of indol, liquefaction of gelatin and coagulation of milk and the species of colon thus determined. The results of these determinations of twenty-four samples, which constituted one run, are appended in the following table:

DILUTION	PER CENT GAS	NUMBER OF COLI PER CC.	DEXTROSE	LACTOSE	DULCITE	SACCHAROSE	MANNITE	RAFFINOSE	MOTILITY	INDOL	NITRATE REDUCTION	LIQUEFACTION OF GELATIN	COAGULATION OF MILK	SPECIES
1.0	....	....	+	+	−	−	+	−	+	+	+	−	+	B. acidi-lactici
0.001	....	....	+	+	−	+	+	+	+	−	+	−	+	B. aerogenes
0.01	....	....	+	+	−	+	+	+	+	−	+	−	+	B. aerogenes.
1.0	....	....	+	+	−	−	+	+	+	+	+	−	+	B. acidi-lactici
0.1	80	60	+	+	−	+	− +	+	−	+	+	−	+	B. aerogenes
1.0	70	6	+	+	−	−	+	+	+	+	+	−	+	B. acidi-lactici
0.1	90	2000	+	+	−	−	+	+	+	+	+	−	+	B. acidi-lactici
1.0	70	2	+	+	−	−	+	+	+	+	+	−	+	B. acidi-lactici
0.01	95	2	+	+	−	+	+	+	−	+	+	−	+	B. aerogenes
1.0	70	80	+	+	−	+	+	− +	+	−	+	−	+	B. aerogenes
0.1	80	20	+	+	−	+	+	+	−	+	+	−	+	B. aerogenes
0.1	70	80	+	+	−	+	+	+	+	−	+	−	+	B. aerogenes
0.01	100	400	+	+	−	+	+	+	+	−	+	−	+	B. aerogenes
0.1	50	100	+	+	+	+	+	+	+	−	+	−	+	B. communior
0.1	85	100	+	+	−	+	+	−	−	−	+	−	+	B. aerogenes
0.1	60	20	+	+	−	+	−	+	−	+	+	−	+	B. aerogenes
1.0	100	6	+	+	−	+	+	+	−	+	+	−	+	B. aerogenes
0.1	80	40	+	+	−	−	+	−	+	+	+	−	+	B. acidi-lactici
0.1	50	100	+	+	−	+	+	+	−	+	+	−	+	B. aerogenes
0.1	80	40	+	+	−	−	+	+	+	+	+	−	+	B. acidi-lactici
0.1	95	40	+	+	−	−	+	+	−	+	+	−	+	B. acidi-lactici
1.0	80	10	+	+	+	−	+	+	+	−	+	−	+	B. communior
0.1	60	40	+	+	−	− −	+	−	−	−	+	−	+	B. acidi-lactici
0.01	85	400	+	+	+	−	+	+	+	+	+	−	+	B. communior

The three samples that gave bacillus communior were taken from points where the river water was kept at a high temperature; in one case by the hot wastes from a tannery, in the second by the discharge of hot condenser water, while the third was taken from the effluent drain of a slow sand filter handling sewage. In other

words, they were taken at points where the temperature conditions more closely approximated that of feces. All the other samples, namely those which show the acidi-lactici and aerogenes type, were taken at points where the river passed through open fields some distance from any sewer. Not knowing the work done by Professor Winslow, Dr. Houston, and others, the speaker felt that he had possibly discovered something new and useful, and continued the work with a view of determining whether or not the addition of the dulcit fermentation test to the ordinary routine procedure for determining the presence of the colon group might not give us valuable additional information as to the probable sources of the organisms encountered.

The speaker is very glad to see that his conclusions were along the right line and that there is a similar but less expensive and more practicable method of determining, with reasonable certainty, whether the colon organism as found in water is of fecal origin or not.

Mr. C.-E. A. Winslow: The speaker wants to make his position entirely clear; he does not think we are in a position to interpret the difference between the types of *B. coli* absolutely, but the work that has been done has been sufficiently promising to warrant its being further looked into. The condemnation of waters on the basis of the lactose bile presumptive test, however, whether they have any trace of the true colon group in them or not, is most unfair; it has led to serious injustice to many water works throughout the country. The accuracy of the tests as applied to certain waters like the Croton watershed is not doubted, but it has been misleading to apply the same tests to other water supplies, which were of high quality. Indiscriminate condemnation of water supplies ought to be stopped because they give the lactose bile presumptive test, unless we are certain they are confirmed by other tests for the group of aerobic bacilli which do not form spores.

A NEW RAW WATER SUPPLY FOR THE CITY OF McKEESPORT, PENNSYLVANIA

By E. C. Trax

The city of McKeesport is situated in Allegheny County, Pennsylvania, at the junction of the Youghiogheny and Monongahela Rivers, at a distance of fifteen miles by river above Pittsburgh. The population is approximately 50,000.

For twenty-seven years the source of public water supply has been the Youghiogheny River, which until 1908 was supplied in the raw state, but during the past eight years has been purified by softening and filtration. A new intake in the Monongahela River is now under construction to obtain a supply of raw water from this stream. It is the purpose of this paper to consider the circumstances and conditions which led to the abandonment of the Youghiogheny and adoption of the Monongahela River as a source of raw water supply.

The first public works to supply water to McKeesport were constructed in 1881. The works consisted of a distribution system, a reservoir on the site of the present distributing reservoir, and a power and pump plant on the east shore of the Youghiogheny River, at a point about one mile above the junction of the Youghiogheny and Monongahela Rivers. Practically all of the original distribution system is still in use; the distributing reservoir, having been enlarged and lined with concrete, and the power and pump plant, having undergone changes and additions from time to time, form parts of the system of to-day.

The water in the river was satisfactory according to the standards of those days, and the intake and pumping station were located at a point which then appeared to be the most convenient and suitable location. Owing to a lack of thorough understanding or appreciation of the influence of water supply upon the prevalence of certain diseases, and also to the fact that the river water was usually clear and free from odors and tastes, this supply was considered satisfactory for some years. While the raw water during flood stage may be very turbid, the flood waters soon run out and it is normally

almost free from color and turbidity. As a matter of fact the supply was superior to certain city supplies in the vicinity until the pollution, due to industrial developments in the Youghiogheny River watershed, became unbearable. As coal mines were opened and admitted their drainage into the river, the supply became acid to such an extent that, in order to bring about some improvement, a series of wells was drilled along the river bank near the pump station. The well water was very hard, contained a large amount of iron, and was not satisfactory bacterially, but was used for many years to dilute the raw water from the Youghiogheny River, thereby decreasing its acidity. In doing this, however, the water supply to the city was increased in hardness by the influence of the water from the wells.

In Water Supply Paper 161, of the United States Geological Survey, published in 1906, it is stated: "It is evident that McKeesport is supplied with a water that is dangerous and in no sense potable or fit for consumption by human beings." The water truly merited this comment. Few municipalities have been supplied with a water as unfit for domestic and industrial uses as that supplied to McKeesport for some years prior to the construction of the water softening plant. It was at times turbid and unsatisfactory bacterially, and when perfectly clear it was corrosive and unfit even for laundry purposes on account of the high hardness, acidity and iron content.

This supply was used without treatment until 1908, and there was from time to time considerable agitation and several studies made as to improvements for relief from the then existing conditions. After investigating the merits of the various suggestions for better water it was finally decided to build a plant to purify the Youghiogheny River water. During 1907 and 1908 a purification plant was constructed on a site adjoining the pumping plant, and the well supply was entirely abandoned owing to the hardness of the water. The purification plant consists of a softening plant and mechanical filtration plant. The raw water is treated with lime and soda ash, mixed, allowed to settle, and passed through rapid sand filters. The results obtained have proven highly satisfactory, and since 1908 the city has been supplied with a water which has fulfilled in all respects the requirements of a first class water supply. The water has been soft and entirely free from turbidity, noticeable color, objectionable tastes and odors, and harmful bacteria. It is true that when a water requires heavy treatment with lime and soda ash there may be sufficient sodium sulphate formed to produce a somewhat flat or

alkaline taste, to which some persons are more sensitive than others. This taste is not usually considered unpleasant and is rarely noticed by regular users of the water. In fact, after becoming accustomed to drinking softened water, it is considered by many more palatable than other supplies. The fact that the softened municipal supply in McKeesport, which is at times probably the most heavily treated domestic water supply in the world, is used almost exclusively for drinking purposes in the city is very strong proof of the potability of a softened water. It is entirely free from the earthy and fishy taste noticed in many surface supplies, and there seem to be no disadvantages or objections to the water for drinking. It is believed that in no city is the public water supply more generally used for drinking purposes and the per capita consumption of bottled table water so small.

According to the present day practice of establishing some relationship between the water supply and the total death rate, the total death rate in the city for twelve years is submitted below. This includes the six years immediately preceding and the six years immediately following the introduction of purified water.

TABLE 1

Total death rate, City of McKeesport

YEAR	DEATHS PER 1000 POPULATION	YEAR	DEATHS PER 1000 POPULATION
1903	21.4	1909	16.8
1904	21.2	1910	20.0
1905	21.8	1911	14.5
1906	19.9	1912	14.8
1907	19.7	1913	13.9
1908*	18.3	1914	11.2

* Purified water first supplied in October, 1908.

This table tends to support the theory that the general health of a community is improved by the introduction of pure water to a much greater extent than can be accounted for by the reduction in typhoid fever alone.

The experience with typhoid fever in McKeesport has been along the same lines as in many other cities where a sudden change has been made from an unpurified river water to a purified supply. An inspection of the typhoid statistics show the death rate to have been excessive in the years previous to the introduction of filtered water in October, 1908.

TABLE 2

Death rate from typhoid fever, City of McKeesport

YEAR	TOTAL NUMBER OF CASES	DEATHS PER 100,000
1900		69
1901		81
1902		87
1903		120
1904		129
1905		63
1906	512	115
1907	330	73
1908*	230	68
1909	128	18
1910	165	21
1911	51	14
1912	41	7
1913	29	5
1914	22	12
1915	26	9

* Purified water first supplied in October, 1908.

These data are included to show that the present supply is safe and highly satisfactory, and for this reason the obtaining of another supply of raw water has been delayed. It has been a case of letting well enough alone.

The Youghiogheny River, the largest tributary of the Monongahela, is about 125 miles in length and drains an area of approximately 1800 square miles. It rises in Preston County, West Virginia, and flows in a general northerly direction, emptying into the Monongahela at McKeesport. The watershed is mountainous, and the runoff is unusually large, especially of late years, as the country has largely been denuded of its forests. This results in floods and low flow in dry weather, and is partly responsible for the violent changes in flow and in the quality of the water.

The river drains a large part of the district known as the Connellsville coke region, and the activity in this vast coal and coke industry resulted in a gradual increase in the discharge of acid mine wastes into the river and its tributaries as more mines were opened. Drainage from coal mines is almost invariably highly mineralized; in addition to the salts of aluminum, calcium, magnesium, sodium and potassium, it usually contains considerable iron in various stages of oxidation, and free sulphuric acid formed by the oxidation

of the iron pyrites which is present in varying quantities in connection with the coal veins. The following analyses represent the condition of some mine waters in this district:

TABLE 3

Analyses of mine waters

	PARTS PER MILLION			
	1	2	3	4
Silica	36	40	26	6
Iron Oxide (Fe_2O_3)	1435	286	780	2
Alumina	113		1985	1
Calcium sulphate	1470	584	1322	None
Calcium carbonate	None	None	None	70
Magnesium sulphate	970	377	310	None
Magnesium carbonate	None	None	None	23
Sodium sulphate	223	170	1150	4875
Sodium carbonate	None	None	None	816
Sodium chloride	30	44	994	320
Alkalinity				870
Free sulphuric acid	452	3667	16,400	None

Nos. 1, 2 and 4 are from mines in operation while No. 3 is from an abandoned working. No. 4 is an example of a highly alkaline mine water.

The effect of a small proportion of mine water in a stream is to lower the natural alkalinity. As the proportion increases the alkalinity is entirely neutralized and the water becomes acid. The flow of the mine drainage is much more constant than the flow of the stream, which is widely influenced by conditions of rainfall and runoff. The effect of the acid is therefore much more noticeable when the river is low and the mine water consequently less diluted with fresh water.

Manufacturing wastes from the plants connected with the iron and steel industry may at times add slightly to these conditions in the streams of this district, but it is believed that the effect of these wastes is almost negligible. It has been estimated that not more than 5 per cent of the acid-iron pollution is due to manufacturing plants.

The water in the Youghiogheny River passed through these various stages as the amount of mine water discharged on the watershed increased. At first it was only during especially low flow in the river that the water was acid at McKeesport. With the in-

crease in the amount of mine wastes, the water has continued to increase in hardness and acidity to the present time. For a number of years the water has been acid at all times except for a few days following heavy rains when the river is high. During the course of this change in the stream a point was reached where fish could no longer live in the water, and they entirely disappeared from the river below Connellsville a number of years ago. The records show that the acidity of the river water has varied from 0 to 390 parts per million. The average reaction for fifteen years is shown below:

TABLE 4

Acidity to methyl-orange in parts per million

YEAR	MAXIMUM	AVERAGE
1901	128	37
1902	204	36
1903	145	30
1904	162	48
1905	72	27
1906	106	23
1907	65	19
1908	240	63
1909	210	31
1910	390	81
1911	180	30
1912	140	30
1913	305	34
1914	280	56
1915	170	24

Following are several analyses of the Youghiogheny River water taken during acid periods:

TABLE 5

Analyses of Youghiogheny River Water

	PARTS PER MILLION			
	A	B	C	D
Silica	21	23	14	20
Iron oxide	73	112	36	106
Alumina	55	52	23	
Calcium sulphate	440	458	194	319
Magnesium sulphate	194	207	99	156
Free sulphuric acid	240	170	110	200

Before the purification plant was constructed the corrosive action of the city supply on pumps and plumbing fixtures was so severe that at times of bad acid conditions it became almost impossible to supply water, and at one time the leakage amounted to 50 per cent of the water pumped. It has been estimated that the saving in plumbing bills alone since 1908 has resulted in an amount more than sufficient to pay the operating costs of the softening plant.

The Monongahela River rises in West Virginia and flows in a general northeasterly to northerly direction, joining the Allegheny River at Pittsburgh to form the Ohio. The total length of the stream is about 225 miles, and the drainage area above McKeesport is about 5600 square miles. In the upper portions the country is mountainous in character and the fall in the stream is very rapid; farther down the country becomes less rugged, but still remains hilly. Below Fairmont the slope of the stream is about 1 foot per mile. The river is navigable to Fairmont due to a series of locks and dams. Mining operations are greatly developed on the watershed and there is a large amount of mine wastes discharged into the drainage basin. The river water between McKeesport and Pittsburgh is acid a greater part of the time, due largely to the influence of the Youghiogheny River. An investigation of the condition of the water in the river above McKeesport was started in 1910, and since that time samples for chemical and bacteriological analyses have been taken almost daily. These records were kept to throw more light on what was then threatening to become a difference of opinion as to which water should be supplied. Even after building the softening plant no grave obstacles were in the way to prevent supplying Monongahela River water to the plant at any time that it might be desired or found to be advisable.

The results of the hardness and alkalinity, or acidity, which is recorded as negative alkalinity, determinations are summarized in Table 6.

Bacteriological analyses show greater sewage pollution than in the Youghiogheny, due to a great extent to the fact that only occasionally is there sufficient acid present to produce a germicidal effect. The number of bacteria developing at both 20° and 37° is generally much higher than in the Youghiogheny River, and presumptive tests for *B. coli* have been positive in 70 per cent of 1 cc. portions of the samples; while for the same period presumptive tests were positive in 35 per cent of the daily samples from the Youghiogheny River.

TABLE 6

Hardness and alkalinity of the Monongahela River water at the Dravosburg Bridge. Parts per million

YEAR	HARDNESS			ALKALINITY TO METHYL-ORANGE		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1910	192	43	70	15	−40	5
1911	142	36	61	30	−15	11
1912	120	43	67	35	−10	9
1913	105	39	59	20	− 9	7
1914	212	44	82	18	−40	2
1915	100	37	64	35	+ 2	6

For the purpose of comparison a summary of the hardness and alkalinity of the Youghiogheny River for the same period is shown herewith:

TABLE 7

Hardness and Alkalinity of the Youghiogheny River water at the McKeesport Water Works Intake. Parts per million

YEAR	HARDNESS			ALKALINITY TO METHYL-ORANGE		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1910	802	40	243	60	−390	−81
1911	510	40	128	45	−180	−30
1912	390	43	144	45	−140	−30
1913	700	45	154	10	−305	−34
1914	708	39	208	12	−280	−56
1915	504	42	141	20	−170	−24

A comparison of the tabulations showing the condition of the water in the two streams reveals a vast difference in the hardness and acidity content. While at times the Monongahela contains free acid and considerable hardening constituents, the amount of acid is comparatively small and the acid periods occur only during exceptionally dry weather, with low flow in the river.

The purification of these acid waters is beset with no special difficulties, the principal disadvantages being the great cost for chemicals and extreme variability in the mineral content of the water. The character of the water in the Youghiogheny River is changing constantly, and variations in hardness and acidity of from 100 to

300 parts per million in the course of a few hours are not unusual. The iron in solution amounts usually to from 5 to 75 parts per million, equivalent to from 1 to 22 grains per gallon of crystallized ferrous sulphate, and there is also present considerable aluminum sulphate. The usual method of treatment for clarification is therefore reversed, it being necessary to supply alkalinity in the form of lime and soda ash to neutralize the acid and precipitate the iron and aluminum. The iron and aluminum sulphates are present in large excess of the amount necessary to completely coagulate the water, and the natural result of this excessive coagulation is a high percentage of removal of turbidity and bacteria in the settling basins. This accounts in part for the high bacterial purity of the city supply since the softening plant has been in operation. It has not been considered necessary to use a germicide although chlorinated lime was applied for a time as an additional safeguard. None has been used, however, for more than four years.

Another factor which exerts a wide influence on the bacterial life is the germicidal action of the acid and iron salts in the river. Considerable sewage is emptied into the river above the water works intake, including the discharge of several sewers from the city itself, and during alkaline conditions of the water the bacterial numbers run very high with *B. coli* present in 0.01 to 0.1 cc. portions. As the water reverts to its normal condition of acidity the number of bacteria falls off rapidly and at times disappears entirely. The agar plates at 37° frequently show no growths, and about 3 per cent of the time during the past seven years no colonies developed on gelatine plates incubated at 20°. Several times sterile water has been obtained from the river, and at times of high acidity tests for *B. coli* are not positive in 10 cc. portions. These results are all the more remarkable in view of the fact that sewers from a populous district of the city flow into the river less than a mile above the water works intake and on the same side of the river.

The treatment of the raw Youghiogheny water has required at times enormous amounts of chemicals. The lime used has varied from 100 to 3800 pounds per million gallons and the soda ash from none to 7000 pounds per million gallons. The average amount used during the entire period of operation of the softening plant has been 866 pounds of lime and 1450 pounds of soda ash per million gallons. The cost per million gallons has been \$3.03 for lime and \$11.72 for soda ash, making a total of \$14.75. Sulphate of iron

and alum have been used occasionally when the water has been turbid and alkaline, but the cost for these coagulants is negligible.

The cost of chemicals as given in the above paragraph, and also the cost of chemicals which are estimated to be necessary to treat the Monongahela River water, has caused some study and agitation since 1908. A report was made to the board of water commissioners in 1912 by Mr. Leo Hudson, consulting engineer, with the coöperation of the writer, and the following quotation is taken directly from the report.

There are several questions which may be argued in considering the Monongahela River as a source of supply, and we have endeavored to give them all due consideration. The United States government is contemplating making improvements in the Youghiogheny River, and if these improvements are made they will unquestionably affect the condition of the river water, in that after rains the pools will be filled with alkaline water which will neutralize for a short time the acid coming down from the coal mines as the two waters mix together. We believe that these improvements will have a tendency to better the general character of the water; but in times of drought the improvement in the water will not last long enough to make it valuable. It has been stated that on account of the development of new coal mines in the Monongahela Valley, the water in this river is constantly getting worse on account of the increasing acidity of the water, and also on account of the abandonment of mines in the Youghiogheny Valley the tendency would be toward improvement in this river in that the acidity would become less. We feel that this conclusion is true regarding the Monongahela, but not true regarding the Youghiogheny. The abandonment of a mine does not decrease the amount of drainage from it, provided it is a drift mine, and the condition of the water coming from abandoned mines and old gob piles is just as bad, if not worse, than that from an active working. Therefore, we claim that the water in the Monongahela River may get worse, due to increasing acidity, but the water in the Youghiogheny River will not get any better. Furthermore, if the improvements which the government contemplates making in the Youghiogheny River are made, the tendency will be to open more mines in this valley, thereby increasing the amount of mine wastes. We believe that this increase will then be as rapid as any increase which may be made in the Monongahela River Valley, and therefore consider that the improvements proposed by the National Government will not ultimately prove of much value in bettering the quality of the Youghiogheny water. Furthermore the drainage area of the Monongahela is considerably greater than that of the Youghiogheny, and the acidity in this river, due to greater dilution, will always be less than the Youghiogheny for the same amount of mine drainage, and it seems altogether unlikely that the actual quantity of mine water discharged on the Monongahela watershed will much exceed that discharged into the Youghiogheny River for many years to come. We believe that it will be many years before the water in the Monongahela River is as bad as the

Youghiogheny from the standpoint of chemical pollution, and that the money saved by taking the Monongahela supply will be well worth while.

There is at times a discoloration in the Monongahela water due to a vegetable stain from the swamps in the Cheat River Valley. This discoloration, however, occurs in objectionable amounts only occasionally following a local flood in the Cheat Valley, and is not injurious.

The bacterial condition of the Monongahela water is unquestionably a great deal worse than the Youghiogheny, but it is believed that this can be taken care of in an entirely satisfactory manner by coagulation, sedimentation and filtration at the present purification plant. The treatment required for the Monongahela supply is a great deal less, and the finished product will be more uniform and give greater satisfaction than the present supply, which at times requires very heavy treatment. The total estimated cost of this improvement is $70,000, and the estimated saving in cost of chemicals is $15,000 per year.

This report was approved by the city authorities, but no steps were taken to provide funds for the improvement. The general satisfaction with the softened supply was so great that it was considered unwise to make a change which was regarded by some as more or less of an experiment. With the great advance in the price of soda ash during the past year it became apparent that the chemical costs of softening the present raw supply would be more than trebled. The building of this new intake became no longer a matter of good policy, but became an actual necessity, and emergency measures were passed by the City Council providing for the quickest possible execution of the work.

This improvement consists of an intake and low service pumping station along the east shore of the Monongahela River about a mile above the point where the Youghiogheny joins this stream. The pumping units consist of three electrically driven centrifugal pumps of a daily capacity of four, five and six million gallons respectively. From this station the water is to be pumped through a 24-inch cast iron main 10,000 feet long to the present purification plant. The cost of the entire improvement will be about $75,000.

The amount of saving effected will depend to a great extent upon the market price of water works chemicals, especially soda ash. At the normal price of soda ash, which for several years previous to the advance due to war conditions was approximately $14 per ton delivered, it was estimated that $15,000 per year could be saved by this change. Under the contract in force at present soda ash costs $50 per ton, and at this price the saving will amount to $25,000 to $75,000 per year, depending upon the condition of the water in the two rivers.

The additional data secured since 1911 bear out in part the premises taken in the report made in 1912. These data indicate that the Youghiogheny River is not improving in quality, greater extremes of hardness and acidity being noted now than in the past for the same stage of water in the river, which is the only rational method of comparison.

On the other hand the water in the Monongahela River does not appear to be growing worse, and while it is still considered probable that eventually the water in this stream will show greater pollution with acid, it is believed that it will be a great many years before a condition exists which will even approach the present condition of the Youghiogheny. The watershed area at McKeesport is more than three times that of the Youghiogheny, and on account of slack water conditions the flow is much more uniform. There are thirteen dams in the river above McKeesport, and the pools formed act as a series of settling basins where considerable purification takes place due to coagulation and sedimentation. The mine water carrying the sulphates of iron and aluminum mingling with the alkaline water of the stream produces naturally the proper conditions for the process of coagulation, and this process is often very complete, the water in the river having the appearance of the water in the coagulation basin of a mechanical filtration plant. There is ample opportunity for the coagulated material to settle out and this produces interesting color changes in the river; in one part of the river the water is brownish yellow in color from the precipitated iron, and as this begins to settle out greenish splotches and streaks appear, giving to the water a mottled appearance; and finally the river appears perfectly clear, or may have a greenish color if the water is acid and contains much iron in solution.

A glance over the results of the hardness and acidity or alkalinity determinations is sufficient to show the necessity of the change in the water supply. With the data available in 1907, and even in 1911, there was room for a difference of opinion in regard to the advisability of obtaining this new supply; but the records now at hand make the wisdom of the change in the raw water supply apparent, and permit of no difference of opinion as to the advisability and necessity of the step taken.

A COMPARISON OF "TEMPORARY HARDNESS" WITH ALKALINITY IN NATURAL WATERS

By A. M. Buswell

The purpose of this brief paper is to call attention to a careless or incorrect use of certain terms for the description of the mineral salts in solution in natural waters. It is in order therefore to recall a few well-known definitions before presenting the data and conclusions regarding these terms.

The total hardness of a water is a measure of the calcium and magnesium salts, carbonates, sulphates, etc., present in the water.

The temporary hardness is the amount of calcium and magnesium salts which are precipitated by thorough boiling. This precipitation is due in part to the decomposition of bicarbonates to form the less soluble carbonates, and in part to the hydrolysis of carbonates and sulphates.

The permanent hardness is the hardness after boiling.

The alkalinity is the sum of the carbonates and hydroxides of the alkali and alkaline-earth metals.

So many writers[1] state, or lead one to infer, that "temporary hardness" in water is equal, or nearly equal, to the "alkalinity" that it seems worth while to call attention to a few typical analyses in which the temporary hardness differs *widely* from the alkalinity. Data will therefore be presented to show that there is a very considerable alkalinity in many waters after boiling.

Mason[2] states that not quite all the bicarbonates are precipitated by boiling and cites an example of a water showing:

[1] Norton and Knowles, A Study of Indicators for the Determination of Temporary Hardness in Water. *J. Am. Chem. Soc.*, 38, 877.

Mason, Examination of Water, p. 26 et seq.

Woodman and Norton, Air, Water, and Food, p. 92.

Purvis and Hodgson, The Chemical Examination of Water, Sewage, and Food, p. 14.

Bailey, Sanitary and Applied Chemistry, p. 67.

[2] Mason, *Loc. cit.*, p. 27.

Before boiling alkalinity = 259 parts per million Ca CO_3
After boiling alkalinity = 28 parts per million Ca CO_3

Since $MgCO_3$ is soluble to the extent of 100 parts per million,[3] and $CaCO_3$ is soluble to the extent of 18 parts per million, and since Na_2CO_3 is not uncommon in water from certain localities, it is obvious that many waters will show a much greater alkalinity after boiling than even the one cited by Mason. Accordingly tests were made on five samples of hard water having the following analyses:[4]

Analyses of hard water

Parts per million

	1	2	3	4	5
Alkalinity	208	222	341	265	880
Total hardness by soap method	245	360	630	380	630
Calcium hardness[5]	190	210	430	230	485
Magnesium hardness	55	150	200	150	145
Free carbon dioxide	11	7	30	7	61
Chlorides	94	16	235	33	800
Sulphates	3	266	188	208	21

These waters are harder than many natural waters, but they are typical of samples received in the laboratories of water-softening concerns, and may with perfect fairness be taken for comparison of "temporary hardness" with alkalinity. Sample 1 had been standing for some time before the boiling tests, mentioned below, were carried out. Its alkalinity had dropped fron 208 to 90 and a considerable precipitate of calcium carbonate had formed on the sides and bottom of the container. Samples 2 and 5 contain considerable amounts of magnesium salts. Sample 5 also shows considerable excess of alkalinity over total hardness, indicating the presence of sodium and potassium carbonates.

The alkalinity of these samples was determined before and after boiling by titrating with $\frac{N}{50}$ sulphuric acid in the presence of methyl-orange indicator. The results are given below.

[3] Kaye and Laby, Physical and Chemical Constants, p. 109 et seq.

[4] Samples were obtained through the courtesy of The Permutit Company,

[5] Winkler, Bestimmung des in natürlichen Wasser enhaltenen Calciums und Magnesiums. *Zeit. f. Anal. Chem.*, 40, 82.

	(1)	(2)	(3)	(4)	(5)
Alkalinity before boiling...........	90	222	341	265	880
Alkalinity after boiling.............	63	110	90	170	345

From the above data it is evident that the term "temporary hardness" is not only not synonymous with, but in many cases does not even approximate the "alkalinity." All five samples showed considerable alkalinity after boiling. Furthermore, the term "temporary hardness" has no greater practical value than to estimate the scale which will form in a tea-kettle. It bears no definite relation to the scale formed in a boiler, for at elevated temperatures and pressures other salts than the bicarbonates are hydrolyzed and decomposed. Nor does the knowledge of the "temporary hardness" aid in calculating the lime required to soften a water by the lime-soda process. The term "temporary hardness" should be abandoned, and only the terms, "total hardness" and "alkalinity" should be used in describing the presence of calcium and magnesium salts in natural waters.

FREEZING OF WATER IN SUBAQUEOUS MAINS LAID IN SALT WATER AND IN MAINS AND SERVICES LAID ON LAND[1]

By William Whitlock Brush

The writer recently stated his experience with salt water as a protection against the freezing of water in mains, and this was followed by a request to develop the subject more fully, including the principles governing the freezing of water in mains laid in salt water and also those laid on land. This paper is prepared in the hope that it may lead to a discussion of this subject and the setting forth of experiences which will be helpful to water works engineers and superintendents.

ICE FORMATION

The transformation of water from the liquid to the solid state, known as ice, as a result of the abstraction of heat from the water, is a process familiar to all, but the exact conditions under which such transformation takes place are not so generally known. This withdrawal of heat may be by means of radiation, conduction or convection, the transfer of heat being accomplished by any one of these agencies operating singly or in combination.

Radiation is the transmission of heat by waves. The earth thus receives its heat from the sun and this heat is in turn radiated from the earth. The sun's rays are shorter than those from terrestrial sources, and will pass freely through certain mediums, such as glass, which are fairly opaque to the longer heat waves from the earth. The color of the body on which the rays strike affects materially both the power of absorption of the waves and the rapidity with which heat is radiated from the body. A black surface most perfectly absorbs and remits heat waves. Radiation of heat has an important bearing on the formation of ice, as will be shown later.

Conduction of heat is a very slow process as compared with radiation and represents heat transfer from one body to another, by con-

[1] Read at meeting of 4 States Section held at Atlantic City, April 8, 1916.

tact. Metal has a very high conductivity as compared with ice and water, their relative conductivities, assuming 1 for water, is 4 for ice and 120 for iron. The high conductivity of iron results in its rapid cooling when in contact with cold air and the conduction of heat from the water in a pipe line through the iron to the air. It is popularly supposed that ice is a much poorer conductor of heat than water. While this is not scientifically true the formation of an ice ring inside of a water main affords protection from a continuance of the freezing process. This is due to the ice ring having a conductivity only one-thirtieth of that of iron, and therefore materially retarding the withdrawal of heat from the water by conduction. Before the ice ring forms the heat in the water is conveyed to the iron through the movement of the molecules of water while the iron carries it to the outside of the pipe by conduction. This process takes place rapidly until the ice ring forms, when the heat in the water can only reach the air through both the ice and iron as conducting mediums.

Convection is the transmission of heat through the movement of the liquid due to a change in temperature, and is caused by a change in density which takes place with such change in temperature. It is well known that hot water is lighter than cold water, and as a result, rises to the surface. In case the air, metal or other substance in contact at the surface or high point is cooler than the liquid, heat will be given off either through conduction or radiation, or both. This process will continue until there is a temperature equality throughout the mass, which in nature seldom if ever takes place. There is therefore almost constant movement of liquids due to temperature differences and the resultant transmission of heat by convection.

Fresh water increases in density as the temperature is lowered, until a maximum is reached at 39° F. There is then a gradual reduction in density to the temperature of 32°, when the liquid changes to the solid form, known as ice, with a specific gravity of 0.89. It is this transformation that is particularly interesting to water works men, and some of the more important features of such transformation will be briefly discussed. The temperature of water is remarkably constant while ice is forming or melting. The temperature of the air may be many degrees below zero, but the temperature of fresh water, even though it be in a rapid running stream, will not be more than 0.01 below 32° F. Again, as long as there is

ice in the water the temperature will only be a similarly small fraction of a degree above 32°F., even though the temperature of the air be many degrees above the freezing point. A mixture of ice and water forms the most constant temperature known to physicists.

It is popularly believed that running water may be lowered to a temperature of several degrees F. below the freezing point before ice will be formed. This is an error. Absolutely still water may be cooled to approximately 10° F. below the freezing point without ice forming, but as soon as there is the slightest agitation of the water an immediate formation of ice takes place and continues until the heat released by the change from water to ice warms the remaining portion of the water to the freezing point. The latent heat of water at the freezing point is large, amounting to 80 calories per gram, or sufficient to raise 143 pounds of water 1° F. for every pound of water changed to ice.

Ice is divided into three kinds, based upon the manner in which it forms, i.e., surface ice, frazil ice and anchor ice.

Surface ice is the common form which appears on the surface of the water when the temperature of the water is cooled to the freezing point. It appears first near the shore and gradually extends out as the deeper water is cooled, the entire surface being eventually covered after the temperature of air remains below the freezing point for a sufficient period to cool the entire surface water to just below 32° F. After the ice is formed, the thickness increases, mainly through the conduction of heat from the water through the ice, it being necessary to conduct not alone the heat in the water but also the latent heat previously in the water, which is released as the water changes to ice. As the conductivity of ice is low, being only one thirty-second of that of iron, this process is relatively slow and the thicker the ice sheet the slower the increase in depth of ice.

Frazil ice is the form which appears in running water when the temperature of the water falls below 32° F. and where an ice sheet cannot form due to the agitation of the water. It forms at the surface and may be made up of flat plates, if the surface is not greatly agitated, but more frequently is in the form of minute needle crystals which join together and form a bulky mass, floating lower in the water than the ordinary surface ice.

Anchor ice is ice which is found attached or anchored to the bottom of a river or a stream, and results from the cooling of the

material at the bottom of the river by radiation, and the resultant freezing of the water which comes in contact with the surfaces, which have been cooled below the freezing point. It will only occur under a clear sky and where there is nothing to interfere with the process of radiation. As dark objects radiate heat more rapidly than light colored ones, anchor ice will form more rapidly on a dark stone than on a light one. It will not be formed under a bridge where radiation is interfered with, nor under ice, which also prevents radiation. When the sun's rays strike the masses of ice, earth and stone, they are absorbed and frequently the whole mass will become loosened and float to the surface. Large rocks are thus raised and carried down stream with the ice.

These three forms of ice are all of interest to the water works engineer, not alone as affecting the problems to be met at the source of supply, when such source may be a reservoir or stream, but also in the distribution of water, as will be shown later.

It is generally considered that ice is a poorer conductor than water. This belief is probably founded upon the very material protection which ice or snow gives against frost penetration. Such protection is mainly due to the resistance of ice and snow to the transmission of the heat waves of radiation. Clear water offers little resistance to the radiation of heat, but is a very poor conductor of heat. Due to the difference in density of water at different temperatures, water will transmit heat through convection, or the movement of the molecules, much more rapidly than will ice, by conduction. The molecules of ice are unable to move freely, and transmission of heat through ice, by convection, is therefore negligible.

Pressure lowers the temperature at which water changes to ice, but its effect is very slight, thus, a pressure of 1 pound per square inch will lower the freezing point 0.009° F. Assuming the normal pressure in a water main to be 40 pounds per square inch, the lowering of the freezing point by such pressure would amount to less than 0.04° F.

The introduction of certain chemicals into the water lowers the freezing point. The most common chemical found is salt, and all are familiar with the lowering of the freezing point caused by the presence of salt. The volume of salt determines the temperature at which the ice forms, the salt being thrown out by the crystallization of the water, so that ice formed in salt water is fresh. The

ordinary sea water will freeze at about 27° F. and the temperature of the water is therefore well below the freezing point of fresh water. As the percentage of salt in the water decreases, the freezing point rises, but this freezing point is probably below 30° F. in the tidal waters surrounding our sea-board cities.

FORMATION OF ICE IN WATER MAINS

The formation of ice in water mains is dependent upon the temperature of the water in the main and the velocity of current, the pressure being of negligible effect, as has previously been shown. It is probable that the water as drawn from a reservoir or stream is seldom below 33° F., as the formation of ice and the density of the water generally prevent the cooling of the water below this temperature. If the water in passing through the main is not reduced in temperature to below 32° F. there will be no danger of freezing. If it is reduced below 32° F. ice will begin to form, the ice forming a coating on the inside of the pipe, due to the high conductivity of the iron. As the ice film thickens, the transmission of the heat of the water to the surrounding earth and thence to the air is greatly retarded, the conductivity of ice being such a small fraction of the conductivity of the iron. If the velocity in the main is reduced through a lowering of the rate of draft, the water in the main is more readily cooled, and the rate of ice formation correspondingly increases. This ice formation may be properly classified as surface ice. It is probable that in a main where the velocity is high, the water is cooled slightly below the freezing point and a form of frazil ice created. Such ice might eventually clog the main, stopping the flow, and the whole mass of water in the main quickly change to solid ice. In the report of the Committee of the New England Water Works Association on the depth at which mains should be laid to prevent freezing, submitted in 1909, reference is made to slush ice forming in a main laid in a salt marsh at New Brunswick, New Jersey. The velocity in this main was high and frazil ice probably formed. A stoppage in flow may also occur after a thaw, due to the loosening of the film of ice which has formed during the cold spell, and which may break up and flow through the water until it reaches a point in the main where the ice may not have broken loose and where the floating ice will become packed in such a manner as to completely stop the flow. While this might

account for the stoppage of flow in mains, especially in house services, after a thaw, which is an experience not uncommon to water works superintendents, there is a record of an actual reduction in temperature of soil below 32° F. following a thaw, and such reduction would be ample reason for the freezing up of water mains coincident with a thaw.

PREVENTION OF FORMATION OF ICE IN SUBAQUEOUS MAINS

Where a main is laid in salt water it is common practice to lay the main without any earth cover. The iron is therefore exposed directly to the salt water, which is usually in motion, and heat may be rapidly abstracted from the water in the main through the three agencies of transmission, i.e., radiation, conduction and convection. Radiation is active in clear water and especially so from the black pipe. The iron is also an excellent medium for conduction, with the heat being absorbed from the surface of the iron by the water flowing over the pipe. Convection will readily do its part within the pipe. The temperature of the salt water, during a period of severe cold, may be lowered several degrees below the freezing point and under such conditions ice will form in the water main and the main will be completely clogged, unless the rate of flow is sufficient to maintain the temperature at the discharge end of the main, at or above 32° F. If a main is laid in a body of fresh water, there is little danger of freezing, except at the point where the main enters the water, as the temperature of the water will be above 32° F. and a covering of surface ice will prevent excessive radiation. If the main is laid in the bottom of a rapidly flowing fresh water stream, it is possible that through radiation and the cooling of the water in the stream, ice might form in the main, but it is improbable that such ice would be of sufficient thickness to interfere with the delivery of water through such main.

EXPERIENCE IN FREEZING UP OF A SUBAQUEOUS MAIN LAID IN SALT WATER AND USE OF ELECTRICITY TO THAW OUT THE MAIN

In February, 1912, New York and vicinity experienced a very cold spell, which commenced on February 3, and continued until February 15. The severest cold was experienced from 11 p.m. on February 9 to 11 a.m. on February 13, the temperature for the first

thirty-six hours of this period ranging from 14° F. to −1° F. During the night of the 11th–12th, the temperature averaged about 13° F. At 9 a.m. on February 12 word was received at the South Bronx Repair Company's headquarters that there was lack of pressure at North Brothers Island. This island is located about 1800 feet from the borough of The Bronx shore, opposite 132d Street. At that time the island was supplied with water by a 6-inch main, 1760 feet in length, laid in 1888, the general depth of the water being 70 feet. This line was exposed at low tide for a distance of about 150 feet from the North Brothers Island shore. An auxiliary line, 12 inches in diameter and 29,700 feet long, was laid in 1906, from Riker's Island to North Brothers Island, Riker's Island being supplied from the mainland by a 12-inch main. The average depth of water in which the 12-inch main was laid was 30 feet. When it was found that the water pressure was reducing, effort was made to increase the flow by opening a fire hydrant and by operating a pump on the island, that was connected to the water main. The evidence at the time pointed to trouble existing both in the 12-inch main and in the 6-inch main. On the morning of February 13, the supply to the island was entirely stopped, and it was not resumed until March 12. At the time of stoppage there had been an extremely low tide and the 6-inch pipe line on the North Brothers Island shore had no cover except rip-rap.

The first trouble was experienced a day and a half after the beginning of the extreme cold spell, and the final stoppage of the main was two and a half days thereafter. The nights during this period were clear, while the days were partially cloudy. The wind was from the north and northwest, with a maximum velocity of 22 miles an hour. The temperature of the river was not taken at this time, but a week later, the weather in the interval remaining at about freezing point. The temperature in the river at a depth of 50 feet was found to be 29° and 32° on the surface. It is probable that the river water was at a lower temperature than 29° when the main was frozen. The weather conditions were ideal for radiation of heat from the main. The temperature of water in the pipe, before it entered the river, was about 34°, this being the recorded temperature of water from the same source that had traveled an equal distance underground. On the main shore end of the pipe, frost was in the ground to a depth of 39 inches, which was 3 inches below the bottom of the pipe.

Effort was made to thaw out the main by building fires around the exposed portion, and using steam hose. A tap placed on the main showed that the main was frozen solid below tide level. As all efforts to thaw the main by ordinary means failed, and as there were about 500 people on the island, mainly patients in a hospital, who could only be served with water transported on boats from the mainland, arrangements were made with the Edison Electric Company to thaw out the main, using electricity. This company started work on March 6, and on the morning of March 7, a current of about 800 amperes at 200 volts was passed through the main, using four 100 kilowatt transformers to step the current from 2000 volts down to 200. During that evening the current was increased to 1000 amperes, on the 8th to 1300 amperes, and on the morning of the 9th, to 1500 amperes and 400 volts, two more 100 kilowatt transformers having been installed. At noon on the 10th, the current was increased to 1800 amperes at 368 volts. As the ice failed to melt, an experiment was tried, a length of pipe being packed solid with ice, closed tight at both ends, and let down to the bottom of the river, and the same current passed through it as was passed through the main. After twelve hours the ice was found to be entirely melted. The current was continued until 6.20 a.m. on Tuesday, March 12, and without any previous warning the water started to flow from the mainland end of the pipe. During the time the current was on, 1000 horse power had been used, it being estimated that thirty-six times as much heat had been generated to melt the ice in the North Brothers Island main as would have been required to melt the same quantity of ice on land. The rapid transmission of the heat from the pipe to the cold water flowing over the pipe was the cause of the failure of this method to thaw out the pipe. On March 12, the date when water started to flow, the temperature of the water was 32°. On the same day the pipe line from North Brothers Island to Riker's Island thawed out, from natural causes.

On March 10, it had been clear throughout the day and night and the temperature had reached 86° in the sun, the maximum in the shade being 41°, the minimum 33°, with an average of 32°. Under such conditions there would be a very material absorption by the water main of heat, through radiation, and with the temperature of the river water up to the freezing point it is possible that the electric current had little effect on the thawing of the

main, although the heat generated by the current was noticeable on the shore ends of the pipe. There is no clear indication of the effectiveness of the electric current thawing the main under the conditions cited.

FROST PENETRATION ON LAND

The Committee of the New England Water Works Association, which reported in 1909 on freezing of water mains, stated in their report that they had received 90 replies from 320 circulars sent out to water works engineers and superintendents, 53 communities had had trouble with freezing of mains, 50 per cent of the freezing had occurred at dead ends, and in all cases there had been little or no velocity. In all but three cases the mains were smaller than 10 inches in diameter, and only seven as large as 8 inches in diameter. In every case the ground was frozen below the axis of the pipe. Forty per cent of pipe was laid in clay, 48.6 per cent in gravel, 5.7 per cent in sand and 5.7 per cent in rock. The depth of penetration of frost was found to be 1 foot greater in the streets than in the fields, and 1 foot 5 inches deeper in gravel than in clay, the depth in sand being about midway between the depth in clay and in gravel. The ice was found at times in concentric rings in pipe as large as 24 inches in diameter, and no stoppage of the pipe had occurred. The ice formation was not always solid, but sometimes in the form of slush. The depth of frost penetration varied materially. The committee called attention to a belief or tradition that existed in the minds of many plumbers and water works superintendents, that most stoppages occurred during a thaw, following a period of severe cold weather, it being suggested that this might be caused by evaporation from the surface during the early stages of the thaw, producing additional refrigeration or reduction of temperature at the depth of a water main sufficient to cause freezing. The committee comment that the reports received did not support this theory. In the discussion of the report an instance was cited where a pipe was laid in the late fall in rock cut, and the backfilling was composed of frozen earth and rock, giving a very porous filling. A comparatively slight current was maintained in the pipe. In the early spring, on a day when it was warm enough so that it was comfortable to be about in shirt sleeves, the pipe stopped up. It was left until the following morning, when it was found that the pipe was again clear.

Mr. Jesse O. Shipman, division engineer, public service commission, New York City, states that, where services are run through bays in the subway, where, in general, the distance from the surface of the ground to the service is about 4 feet, with 6 inches of earth below the service and 12 inches of concrete forming the roof of the subway, trouble from the service clogging with ice usually occurs a day or so after a thaw, following a severe cold spell, has set in.

The writer endeavored to find records of ground temperature but was able to locate only those of Profs. H. L. Callendar and C. H. McLeod of McGill University, Montreal, Canada, and recorded in the proceedings of the Royal Society of Canada for the years 1895, 1896 and 1897.

These experiments were started in 1894 by Professor Callendar and he was later assisted by Professor McLeod. The location selected for the experiment was level ground in a garden where there was turf and loose light brown sand to a depth of 8 feet 6 inches. Below this sand was stiff blue clay to a depth of 30 feet from the surface. Water was found in the sand for some distance above the clay but the sand was nearly dry to a depth of 5 feet.

A trench 3 feet wide and 9 feet deep was dug, with one face vertical. Into this face horizontal holes were bored for nearly 3 feet, using a one-half inch rod. Electrical resistance thermometers, consisting of a carefully insulated coil of platinum wire about 3 inches long and protected by an external tube of glass or copper, were inserted in these holes and connected to the indicating apparatus by insulated leads of convenient length. The holes were bored at depths of 1, 4, 10, 20, 40, 66 and 108 inches. In the earlier periods readings were taken daily at 12 noon, but later a continuous recording apparatus was installed. An abstract of the snow conditions and temperatures recorded will be found on pages 972 and 973.

This record shows very clearly the material effect of snow on the depth of frost penetration and the slight cover probably required when snow is always present early in the winter. The record of the thermometer buried at a depth of 10 inches, which showed in April, 1895, a drop of 0.2 to 0.3° below 32°, which was the temperature at the beginning of the thaw, is very interesting. This shows that a lowering of the ground temperature below 32° F. may result from a thaw. The following notes are copied from the text:

Winter 1894–1895

DEPTH OF THERMOMETER	PERIOD TEMPERATURE WAS BELOW 32° F.	MINIMUM TEMPERATURE	SNOW CONDITIONS
Air	Dec. 20 to Mar. 20	−10° F. in Feb.	10 inches snow Dec. 28 which increased to 21 inches by Feb. 1, 33 inches by Feb. 7. Began to melt in March. Final melting of snow between Apr. 7 and 14
1 inch	Nov. 25 to Apr. 14	27° F. in Dec., just before snow fall	
4 inches	Nov. 28 to Apr. 14	28° F. in Dec., just before snow fall	
10 inches	Dec. 16 to Apr. 14	31½° F. in Dec., just before snow fall	
20 inches	0	33°F. Dec. 14, melting snow	
40 inches	0	35½° F. Apr. 20, melting snow	
66 inches	0	38°F. Apr. 21, melting snow	
108 inches	0	41½° F. Apr. 22, melting snow	

Winter 1895–1896

DEPTH OF THERMOMETER	PERIOD TEMPERATURE WAS BELOW 32° F.	MINIMUM TEMPERATURE	SNOW CONDITIONS
Air	Nov. 20 till Apr. 10 except for short rises	−15° F. Feb. 18	Practically no snow till Jan. 24. The winter is remarkable for lateness of heavy snow fall and for the rapidity of its disappearance. Light snow fell in Nov. and Dec. disappeared. Heavy snow fall commenced Jan. 24 and increased to maximum of about 30 inches in March. Snow disappeared about April 12
1 inch	Dec. 2 to Apr. 20,	27° F Jan. 22, before snow fell	
4 inches	Slightly shorter period than for 1 in.	28° F. Jan. 22, before snow fell	
10 inches	Dec. 22 to Apr. 20,	30° F. Jan. 22, before snow fell	
20 inches	0	32½° F. Jan. 23	
40 inches	0	34½° F. Apr. 15, melting snow	
66 inches	0	38°F. Apr. 20, melting snow	
108 inches	0	41° F. Apr. 25, melting snow	

The final thawing of the ground took place at a depth of 10 inches on April 19. The 10 inch thermometer which had remained within less than 0.1° F. for about two months previously, showed a depression of 0.3 when the thaw reached it, probably due to lowering melting point by dissolved salts. . . . . The percolation of water caused a slight simultaneous fall in the two thermometers next below.

Winter 1896–1897

DEPTH OF THERMOMETER	PERIOD TEMPERATURE WAS BELOW 32° F.	MINIMUM TEMPERATURE	SNOW CONDITIONS
Air	Nov. 15 to Mar. 20	Mean temperature air Dec. 23, 5° F.	No snow during early part winter; frost penetrated much deeper into soil than during two years previous; thawing of ground after disappearance of snow was lengthy operation; 20 days were required. Temperature at 20 inches did not rise above freezing till May 1
1 inch	Nov. 23 to Apr. 3	10° F. Jan. 20	
4 inches	Dec. 1 to Apr. 10	12° F. Jan. 20	
10 inches	Dec. 15 to Apr. 18	19° F. Jan. 20	
20 inches	Jan. 5 to Apr. 25	27° F. Jan. 20	
40 inches	Nearly reaches 32° F. during Mar. and April	33° F. Mar. and Apr.	
66 inches	0	36° F. Apr. 22, melting snow	
108 inches	0	39° F. May 2, melting snow	First fall of snow quite light Dec. 5. Practically no snow till Jan. 20. About 20 inches snow on ground from Jan. 20 to Feb. 20. About Feb. 20 snow increased gradually and uniformly to about 28 inches by Mar. 1. Snow disappears about Apr. 2 or 3

This record obtained in a carefully conducted experiment is confirmation of the possibility of a thaw causing the freezing of water pipes. The rapid lowering of ground temperature by cold water percolating through the ground was strikingly shown several times during the period covered by the records. While percolating waters may lower the temperature, the presence of moisture reduces the likelihood of services freezing, for the following reasons:

(a) The freezing of the water releases latent heat which is transmitted to the ground.

(b) The frozen ground is a poor conductor of heat.

(c) Water is a poor conductor of heat, and when it is held in the ground by the action of capillarity, it cannot readily conduct heat by convection, as it would if it were free to move.

PREVENTION OF FORMATION OF ICE IN MAINS AND SERVICES

Where frost penetration has extended to, and possibly beyond, the level at which a water main or service has been installed, the water in the main or service will freeze unless the temperature of the water in such main is kept at or above 32° F. This can only be accomplished by having such quantity of water pass through the main that the rate of abstraction of heat will not be sufficiently rapid to cause the temperature of the water to fall below 32°.

As has been pointed out, in the supply from the Croton River, the temperature of the water, even during a very cold spell, is found to be about 34°. As long as there is sufficient water passing through the mains to prevent this temperature being reduced by more than 2°, i.e., to 32° F., there will be no danger of freezing of water in the mains. By testing the temperature of the water as it is drawn from a hydrant, it can be determined whether there is or is not likelihood of the main freezing. No rule can be formulated which would answer the question as to whether a main will freeze under given conditions. A protecting covering is certainly a great aid in reducing the danger of freezing, and snow on the ground is an almost sure preventive.

THAWING ICE IN MAINS AND SERVICES

The problem of thawing out frozen mains and services has been greatly simplified through the utilization of the electric current at low tension. While it was found that this method was not of much value when applied to a main laid in water, where the heat generated through the passage of the electric current would be rapidly dissipated by the flowing current of water, the condition where the pipe is covered with soil is entirely different and much more favorable to the thawing of the main. As the electric current passes through the metal, the heat generated will thaw both the ice which is formed within the main and the ice which is formed in the soil outside of the main. The transmission of this heat to the

surrounding earth and thence to the surface is very slow and a comparatively small amount of current is required to make the necessary change from ice to water. It is not necessary to describe the actual application of electricity to the mains as this has been set forth in detail many times.

The writer found in his investigation of this subject that a study of the formation of ice in streams has greatly aided him in obtaining a clearer conception of the conditions under which ice is liable to be formed in mains, and on this subject he has drawn freely from the "Treatise on Ice Formation," by Howard T. Barnes, Associate Professor of Physics, McGill University, Montreal, who has made extensive experiments and observations on ice formation in the St. Lawrence River and elsewhere.

DISCUSSION

Mr. C. R. Wood: Will Mr. Brush tell us whether in his studies of ice action he ran across any theories as to the melting of ice At Eaglesmere, Pennsylvania, where Mr. Emery's plant is located, the ice, which is cut at a temperature well below zero, as a rule does not melt nearly as fast in household use as the ice supplied in Philadelphia, whether it is manufactured or natural ice cut in Pennsylvania, near Philadelphia.

Mr. William W. Brush: There would be a difference in the rate of melting of ice that was cut at a very low temperature. If the ice itself was materially below the freezing point, it would be very much harder, as ice at the lower temperatures is much harder than ice at the higher temperatures. It will also require the absorption of a certain amount of heat to bring the ice up to the melting point, although that heat is rather small compared with the heat which is absorbed in the change of structure from ice to water. The difference in the rate at which ice that had been cut at the low temperature would melt as compared with the ice that had formed at ordinary outdoor temperatures would be rather small. Artificial ice is cooled only very slightly below 32°, and so it is in a condition where it would probably change very quickly to water. It would be very interesting to get statements as to the conditions under which ice has formed and the character of ice. Personally, the speaker has had very little experience with cutting mains when

they were frozen and examining the ice in them. In the case of the pipe under the East River, there would be no question but that the ice would be very solid, because that main had been exposed many days to a temperature of 29° without any flow of water through it. The condition under which slush ice has stopped up the mains, and the appearance of the ice when examined, would be very interesting, and also the experience of those present at the freezing of mains after a thaw. The speaker does not know whether the theory set forth is the correct one as to the stopping up of the mains, but it would only be by obtaining the experience of the different men in the freezing of mains that we could hope to get the correct theory as to the stopping of services after a thaw, which is a matter interesting to a good many of us.

Mr. Carleton E. Davis: Have you any set of questions that might be sent out to get a wide range of answers? Could you suggest any change from the New England Water Works Association questions?

Mr. William W. Brush: The New England Water Works Association questions were directed mainly to the question of depth of cover. They were not directed to the question of the formation of ice from the viewpoint of the character of ice formed. If questions were to be sent out, a different line of inquiry would be developed by such questions from the line of inquiry developed by the New England Water Works Association Committee. The speaker has not up to the present time given that matter any personal consideration, but it might be interesting to have an inquiry sent out to obtain all information that could be developed as to the way in which the ice was formed, and the character of ice noted when the main was cut, in case any of the mains have been cut when frozen.

Mr. George S. Cheyney, Jr.: The speaker has had a little experience along this line. We have a reservoir holding 2,000,000 gallons; this is about 10 feet deep and there is a 12-inch inlet pipe and a 20-inch outlet pipe passing under the reservoir embankment. The reservoir is constructed of earth embankment, about 10 feet wide on top with an extreme height of probably 15 feet, with $1\frac{1}{2}$ to 1 slopes, so that there is about 50 feet of width of embankment at the bottom. A short distance from the outside of the embank-

ment a gate house is located, with a basement approximately 10 feet deep. The inlet and outlet pipes referred to, pass through the basement of this gate house, and on the outlet pipe there is located a wrought iron screen pot, about 3 feet in diameter. The screen in this pot has been choked up with something like slush or anchor ice on three different occasions in the past eight years. The first time it was reported the surface of the reservoir was found to be covered with unbroken ice which was several days old. At the time of this trouble the flow from the reservoir was practically stopped by the ice and an examination showed the upper half of the screen pot to be practically filled with ice. The next trouble occurred two years ago and at that time there was no ice on the reservoir. There had been a very heavy snow squall in the afternoon with a high wind blowing toward the gate house; probably 2 or 3 inches of snow fell in fifteen minutes. The screen was again choked up in the same manner a few hours after this, and the trouble at that time was attributed to the saturated snow which it was thought had been blown over to the side of the reservoir next to the outlet pipe, and carried into the screen pot. The third trouble occurred last winter, when the reservoir was covered with a heavy cake of ice several days old. The anchor or slush ice was again found in the screen pot, and practically stopped the flow. The chamber in which this screen pot is located is about 10 feet deep, all below the ground level, and at about the ground level there is a cement floor, so that it is well below the frost level. The gate house is of masonry, about 18 feet in diameter, which makes it seem impossible that there should be any freezing in the screen pot itself, on account of its location. A number of small pipes and gate valves with bonnets in the same chamber have never caused any trouble from freezing. There are about thirty similar reservoirs under the speaker's charge and this is the only one where trouble of this kind has been experienced. The reservoir is located on the top of a hill in an exposed position, where it gets the northwest winds, but it is no more exposed than many others where no trouble is experienced.

Mr. William W. Brush: Are the other reservoirs of a greater depth?

Mr. George S. Cheyney, Jr.: They are practically the same, probably 15 feet depth of water at the outlet. The reservoir referred

to is 40 miles west of Philadelphia, where we do not have very extreme temperatures.

MR. WILLIAM W. BRUSH: The formation of ice under those conditions would necessarily come from the water being very nearly, if not quite, at 32° temperature at the time it enters the chamber, and a chilling in the chamber. It would be very interesting to know what the temperature was in the chamber at the time, because it was so clearly shown in the St. Lawrence River experiments that the water must be chilled below 32°, but it will not be chilled more than 0.01° F. before the frazil ice or the slush ice will form, so if there is anything at this reservoir that would cause that very slight cooling of the water, slush ice would form in the valve chamber.

MR. GEORGE S. CHEYNEY, JR.: Would you not expect it to freeze around the outside of the chamber forming a coating, rather than to form slush ice?

MR. WILLIAM W. BRUSH: In the chamber the agitation and velocity were probably sufficient to prevent forming of a coating. Did the slush ice form before it struck the screen or at the screen?

MR. GEORGE S. CHEYNEY, JR.: The screen divides this chamber into two equal parts. Most of the ice, of course, is on the screen, but apparently the whole upper part of the screen pot was more or less filled with slush ice.

MR. WILLIAM W. BRUSH: It would seem as though that must have been chilled by the exposure to the air at that point.

MR. GEORGE S. CHENEY, JR.: A 20-inch pipe line on a bridge exposed for a length of about 2000 feet is covered with the usual covering and we have been thinking of dispensing with this covering, and made some experiments to determine the temperature of the water in the pipe line at the ends of the bridge, using recording thermometers. These experiments were not very satisfactory on account of the inaccuracy of the thermometers. In connection with this we made some rough laboratory experiments to determine whether water at 32° F. flowing through an exposed pipe line would retain enough heat units to prevent it from freezing. The experi-

ment was made by sinking a thin metal vessel containing water in a larger vessel containing brine at zero temperature. The water in the inner vessel was kept constantly stirred and its temperature fell to 32° F. where it remained and no freezing occurred except a ring around the outside which was in contact with the metal. This ring of ice gradually increased in thickness while the water in the center of the vessel was kept in its liquid state. The experiment seemed to prove that a ring of ice could be formed on the inside of the pipe through which water is flowing even though the water itself contained sufficient heat units to prevent freezing.

Mr. William W. Brush: That would be true. The water in direct contact with the mains would probably freeze first in any main and form a film of ice inside of the main. Then if the intensity of cold were sufficient to lower the temperature of the water inside of the main, inside of this ice coating, to just slightly below 32°, even though there was comparatively high velocity, this frazil ice would be apt to form.

Mr. George S. Cheyney, Jr.: In the experiments the only ice that formed was a ring against the metal on the outside and that gradually increased in thickness. The water kept constantly at 32° F.

Mr. William W. Brush: Professor Barnes states that he tried the experiment and produced in the laboratory this frazil ice by agitation of the water, and it would freeze on the inside of the vessel which was exposed to the extraordinarily low temperature of water outside, but he produced the frazil ice, rather than the solid ice, in the laboratory.

Mr. George S. Cheyney, Jr.: That would be a question of radiation, if the radiation were rapid enough to keep the water temperature down to 32°, you would not get the frazil ice?

Mr. William W. Brush: You would not; you would have to have rather rapid radiation and get the water just super-cooled or slightly below 32°, and then the frazil ice would start to form. The case mentioned, which was reported in New Brunswick, seems to be the nearest to the formation of true frazil ice in a water main

where it was in salt water and where it filled with slush ice at a comparatively high velocity through the main.

Mr. Carleton E. Davis: The speaker recalls one instance where frazil ice performed a good service. The Newark Water Works has two lines of steel pipe. One very cold winter night the supply was cut off. It was found that ice had accumulated on the racks at the intake to such an extent it had cut the water off. There was no way of removing the ice, so they pulled up the racks and let the ice go down into the pipes. That pipe was badly tuberculated, the frazil ice removed all of this tuberculation, thereby increasing the carrying capacity 5 per cent.

Mr. Earle W. Meckley: When investigating the pipe going over to North Brothers Island did you notice any greater heating of the water at the change of tide? You said at the ends of the pipe you noticed the heating of the water when the electric current was applied. Was there any greater effect in the heating of the water when the tides changed, because then there could not be that rapid conduction of hot water from the outside of the pipe by the flow of the water?

Mr. William W. Brush: That raises a point which was not investigated at the time. It would be interesting to see whether at about the time the ice gave way in the main there was a change in the tides. There would undoubtedly be a greater effect in the passing of the electric current through the main at the slack tide, but the department did not have any means of accurately measuring the temperatures, and only attempted to get a rough determination of the temperature of the water in the river to see whether it was low enough to be responsible for the freezing of the main.

EXPERIENCE WITH LEADITE IN JOINTING CEMENT-LINED WATER PIPE

By W. H. Buck

The subject of using leadite for making joints in cast iron bell and spigot water mains has been discussed at different conventions and several papers have been written about leadite in this connection. It may interest some of the water works fraternity to hear something about leadite for making joints in cement lined water mains.

For several years prior to 1910 leadite as a pipe jointing material had been considered by the writer, and finally, some time in July, 1910, it was given a tryout on a short spur of a little over 1000 feet of 4-inch water main laid on the outskirts of Palmyra. This seemed to be a good place to try it, because, in case it did not come up to the standard, the remaking of the joints would not inconvenience anyone much. If the leadite proved satisfactory on this line, it was the intention to use it on quite a number of extensions which the company contemplated laying later in the season, including a 16-inch cement pumping main, and various spurs and feeders ranging in size from 4 inch to 16 inch, making a total of several miles of new mains.

Well, after pouring the last joint on the experimental line of over 1000 feet, the water was turned on, and every joint after careful examination was found to be bottle tight. The gratifying result of this experiment gave confidence to tackle the larger operation with leadite, which was done with the most satisfying result. A few slight leaks occurred, or sweats rather than leaks, which took up, and were absolutely tight within forty-eight hours. The writer has never had to make over a leadite joint, or found a joint made with leadite on our whole system that showed the slightest sign of a leak after it had once closed up.

From this experience, it seems safe to believe that a leadite joint once tight is good for all time. Another thing, when occasion arises to cut out a joint for different reasons, such as cutting in specials, valves, etc., a man with the proper tools can cut out a 6-inch leadite joint in about twelve minutes, where it would take the same

man much longer to cut out a lead joint of the same size. Then, too, a wet joint can be poured successfully with leadite without the slightest danger to the workmen, this having been done a number of times in the last six years and always with success. It is often very difficult and dangerous to pour wet joints with lead. Of course it is always better to have the joint dry for either leadite or lead, but at times there are circumstances which make it necessary to pour a wet joint.

Some people think it is difficult to handle leadite, but it is not necessarily so. If you have your joints thoroughly clean from all dirt, and yarned up tightly with a good dry yarn, and the leadite properly melted, success should crown your efforts.

One ton of leadite will do as much work as 5 tons of lead. The manufacturers claim that 1 ton of leadite is equal to 4 tons of lead, but leadite goes further with us because we make our joints 2 inches instead of $2\frac{1}{2}$ inches deep as specified by the leadite makers. Also much less labor is required for putting leadite in, and probably every one will agree that labor, at the present time especially, is an item worth considering. In the first place there is no caulking necessary; this brings the cost of digging bell holes down to rock bottom, as they need only be large enough so that a man can drive the yarn in. The cost for freight, carting, and handling, etc., is about one-fourth of that for lead. Leadite in the writer's opinion, if handled right, is the best and most economical jointing material on the market today.

DISCUSSION

Mr. D. W. French: In the event of a leadite joint being improperly poured, or possibly leaking, is it not a fact that it must necessarily be cut out and rerun; that it cannot be caulked?

Mr. W. H. Buck: If a leadite joint does not run perfectly, or if for some reason you have a leak, or the joint is not perfect from any cause, you can cut the imperfect part out, and bank it up with clay, and after that part of the joint is again fused it will be just as good as though it were all poured at one time. A joint can be partly made, or it can be poured with one or more pours and it will be perfectly tight.

Mr. D. W. French: If it is made and it is a failure, it is probably due to improper temperature, is it not?

Mr. W. H. Buck: Very largely so. If the leadite is too hot it becomes thick and gummy; if too cold, it will not fill out as it should. The proper temperature for leadite is about 400°. It does not take an expert to get the correct idea of when the leadite has arrived at the proper temperature, for when it does that it is just like the surface of a mirror, there is no froth, no bubbles or anything like that on the surface; you can see your reflection in it as you could in a mirror; then is the proper time to pour. The speaker has gotten up tools of his own for handling leadite. One tool, like a ripper, such as is used on a boiler tube, or virtually a cape chisel, is made on a bevel so that it will go between the spigot end and inside of bell, and a joint can be cut out with it. It cuts very rapidly. The speaker has cut out a 6-inch joint in nine minutes. Some of his men have cut out a joint in less than twelve minutes.

Mr. D. A. Reed: Has the gentleman ever used leadite for joints in pipe laid under a railroad track, where it is subject to excessive vibration; and if so, has it been successful?

Mr. W. H. Buck: No. That condition has not been encountered.

Mr. D. A. Reed: Does leadite shrink, or expand in joints?

Mr. W. H. Buck: It expands. It must be poured hot, and as it gets colder it gets tighter.

Mr. J. M. Diven: There is no subject that has been brought up before this convention on which we have had more conflicting testimony than with reference to leadite. One member praises leadite to the skies; another utterly condemns it; many of them men of large experience and very careful in research work. This leads one to believe that there is something peculiar about the handling of it; there must be some knack. It must be that the temperature is not always exactly right. If it is going to be a success we ought to have some absolute knowledge as to what the temperature should be in pouring, or some means of controlling the temperature when melting in the pot.

Mr. W. H. Buck: The temperature is very essential. Another important matter is the cleanliness of the joints. The speaker never employs an old time lead caulker on a leadite job, but takes men out of a gang and makes yarners and joint makers of them; because the old time lead caulker seems to have a certain amount of prejudice against leadite, and there is where the trouble arises to a very large extent when people make a failure of leadite.

Mr. J. M. Diven: If it is over heated in melting is it spoiled?

Mr. W. H. Buck: No, after a little experience one becomes accustomed to the proper way of melting so that he can do it to a nicety. The speaker has a four burner gasoline furnace; to start, the pot is filled half full of the powder, the four burners are allowed to burn until the powder is partly melted, then one burner is turned off, and more of the raw material is put in; at intervals another burner is turned off, until only one remains. The leadite should be stirred constantly with a ladle until it is practically all dissolved. If you keep the ladle hot you can get right down to the bottom. Always stir from the bottom thoroughly, and then if the joints are not ready to be poured turn the flame of the burner down to just a flicker, and before you take out a ladleful give it a stir two or three times, then take out your ladleful and pour. Cement pipes can be poured practically ten joints at a time, that is for every 100 feet, the pipe being in lengths of 9 feet 5 inches. The furnace is moved ahead 100 feet at a time. Just as soon as the joints are poured another batch is gradually melted, so that there is not an excessive amount on the fire at any one time, thus preventing thickening of the leadite.

Mr. J. M. Diven: There is considerable sulphur in this composition, and sulphur is not healthy for cast iron, and less so for wrought iron. From the investigations that you have made can you say whether there is any danger from the action of the sulphur on the iron?

Mr. W. H. Buck: There is nothing more susceptible to corrosion than steel. On the spigot and bell ends of cement pipe there is headed on by an acetylene process a reënforcing jacket of steel. On taking out fire hydrants, joints that were made six years ago, have not shown the slightest bit of corrosion of these jackets.

Mr. D. R. Gwinn: We have had some experience with leadite at Terre Haute. About seven years ago we put in a couple of blocks of 6-inch pipe using leadite for joints, and we let them stand for a year or two to see how it would work, then dug up the joints and found them in good condition; so then we laid about five miles of pipe from 6-inch to 12-inch, with leadite joints. It recalls the famous little girl who "when she was good she was very, very good, but when she was bad, she was horrid!" Leadite when good is very fine, indeed, but when it does not work out all right, then it is like that little girl. A great deal depends upon the man who is running the kettle; if he gets too much fire and lets the leadite apparently boil he will not get very good results. One job that was put in in a hurry gave a great deal of trouble. The street was paved shortly afterward, and has been dug up presumably fifteen times in about a half mile of pipe. Then in other cases we have never had a particle of trouble.

Again, a great deal depends upon the end of the spigot being thoroughly clean. You must have, also, hemp which is not oily. These are the main points; that you have a good man to attend to the kettle; that the substance is not allowed to boil off too fast; and that some one watch the pipe to see that there is no foreign substance on the spigot and in the bell, but that both are thoroughly clean, and that the hemp is all right. If these conditions are observed you will get very good results. One great advantage is that you do not have to dig deep bell holes, and you can make pretty rapid time laying pipe.

Mr. W. E. Miller: Would an ordinary gasoline blow-torch answer for melting out leadite joints?

Mr. W. H. Buck: Yes, but you will find that it will be slower work than with an oxygen blow-pipe. The quickest way is to cut it out, unless you have an oxygen blow-pipe.

Mr. J. M. Diven: Do you refer to the oxy-acetylene outfit?

Mr. W. H. Buck: Yes.

Mr. J. M. Diven: It melts at a lower temperature than lead, does it not?

Mr. W. H. Buck: Yes.

Mr. J. M. Diven: For that reason it should be much easier to melt out than lead.

Mr. W. H. Buck: It is.

Mr. D. W. French: From what Mr. Buck said he has had occasion to cut out a great many joints for one reason, or another; and the speaker has been wondering what the reason was for his having had to cut them out.

Mr. W. H. Buck: In making inspections or putting in special valves.

Mr. D. W. French: Not because of trouble in pouring the joints?

Mr. W. H. Buck: No, indeed.

SUPERINTENDENTS' DAY

DISCUSSION OF PRIVATE FIRE SERVICES

MR. WIRT J. WILLS: In starting on this very important subject, which has been nearer and dearer to the speaker than any other for about six or seven years, he just wants to emphasize what our secretary has said: "This is a question that is bothering most of us, let us try at this convention to 'get somewhere' with it. Let each one tell his experiences and methods, and then select the best of these, and from them try to make up a standard."

That is what the speaker wants to emphasize to all of the members, let us do something today. Some of you will remember arguing on this line in Minneapolis when our worthy President Mr. Gwinn reminded the speaker of the fact that the American Water Works Association had passed a resolution to make a charge according to the rules and regulations for fire protection. Now that was in 1906 or 1908, and here it is eight years since then, and we are no nearer to getting together on the subject than we were before. So before going into this subject are there not some persons here who are not vitally interested because they have solved the question who would help some of the rest of us to get somewhere today. Let us do something and try to get somewhere.

MR. LYMAN P. HAPGOOD: Having been through this same proposition, we feel that our troubles are all over now. We furnish fire protection to the city of Jamestown which seems to be ample; that is "ample" because it is accepted by underwriters as being satisfactory. We furnish fire protection to the public at large at no expense to the public beyond a nominal charge of $12,000 a year, which charge includes hydrant rentals and all municipal use of water. There are between five and six hundred hydrants in the city.

Now if we have done all that and in a satisfactory manner, we see no reason at all why Tom, Dick or Harry should want added fire protection to benefit themselves financially. That is to say, if anybody puts in sprinklers he gets a reduction in his insurance, and if he wants special fire protection he certainly should pay for that special privilege. We do not charge him anything for the water he uses to

put out fires, but we do charge him for the connection from the main, including the meter. We furnish the water free. We furnish the service pipe to the curb free for all other uses; but having furnished ample fire protection we say that if he wants added fire protection he must pay for it; that is, he must pay for the installation of his pipe and his meter, and we will furnish the water to put out his fires. This plan has been in operation in Jamestown now for two years. The first year and a half it was somewhat difficult to get the thing through, because the factory owner or the property owner felt that we were imposing upon him; but we got it started, and we have over 20 detector meters on. We are having no trouble a out putting them in now, everybody seems to be satisfied; and it seems that is the only way to do. There should be no absolutely free service.

Mr. Harry F. Huy: The question of proper compensation for fire service in the territory of which the speaker has charge has been very thoroughly considered, due to the fact that we supply water to very large industrial consumers.

In the first place, the water company considers it is proper that it should not make the consumer pay for the meter or own the meter; but that the water company should own and keep the meter in repair; and be responsible for the meter itself; so that it will have the exclusive right to go into the premises at any time and make repairs, test, adjust or replace the meter without consulting or negotiating with the owner.

The water company should be allowed to make a service charge commensurate with the amount and character of the service rendered. The practice of the company is to make a service charge for each hydrant and an additional charge for any water that is used in connection with the hydrant. This protects the water company against improper use of the fixtures. We have found, in a number of cases, where we had a fire hydrant, whether it was sealed or not, someone opened it and used the water for other purposes. Upon taking the matter up with the consumer apologies were forthcoming but unfortunately the revenue was lost to the water company.

Is not the logical way of handling fire protection service to make a service charge, depending upon the amount of fire protection, taking into account the number of hydrants and sprinkler heads installed; the water company to furnish the meter and the pipe in

public streets, the consumer to pay for all pipe on private property; and if any water is used on the service, payment for all water registered by the meter to be made by the consumer at the uniform schedule of rates?

Mr. Albert Blauvelt: Presumably the bringing up of these questions is with the thought of getting at a sort of recapitulation of present day thought.

Some water works men seem to look upon insurance interests as an indivisible sort of a unit, and that any particular trouble with one insurance unit applies to all the rest of them, but as a matter of fact, the business of fire insurance is considerably bigger than the United States post office, and unlike the post office is divided into a great many divergent groups which have no commercial affiliation whatever.

As to anything responsible on paper as representing the insurance standpoint on this subject there is almost nothing. All that you can get out of insurance men is individual opinions. Now taking the question as to whether a private fire service is one of the proper functions of a water works, the same as the public hydrants, or a valuable and special service tendered to a certain citizen, a service that should be paid for by the one receiving the benefit; that is a legal question in some cases, but not in most cases. There are not very many corporation charters, or very many city charters which cover that point so that you can get legal rules; and in the absence of any legal definition it seems that for service that comes inside of a private property, that private property must be held responsible and must pay for it, whether the corporation be in the form of an incorporated water works or a city incorporation, the water works being one of its branches. Now, if that view be correct, it answers the question, that the private property benefited should pay the entire cost of installing and maintaining such service.

There has been considerable discussion as to whether pressure service is a good and valuable service where no water is consumed. The speaker is very emphatically of the opinion that pressure service with no consumption is a good and valuable service. If not, why do the parties want it?

As to whether this service should be confined to factories or extended to commercial houses or even residences if desired, it seems that for a private service the character of occupancy of the property

does not make any particular difference, for the property is responsible in any event.

The general installation of such services would make special provision for their care by the water works necessary; because of the necessity of inspection of all pipes, even if installed on private property; and that inspection necessarily requires supervision, which might become a considerable job, if there were a number of private services.

As to the size of service allowed and its proportion to size of mains; the printed rules for the installation of automatic sprinkler systems, state that the connection for automatic sprinklers should not be less than 4 inches. There has been quite a good deal of getting together on that point; and while there is more or less of a demand for connections larger than 4 inches, yet a good many water works have said that they would allow 4 inches, but nothing larger; and that is now the rule of practice in some very important cities. At the present time there seems to be quite a fair consensus of opinion on the part of important water works in limiting the size to 4 inches, thereby meeting the expression in the sprinkler rules asking for connections not smaller than 4 inches. The question as to whether more than one 4-inch connection should be granted is rather an open question as yet. Scme water works, in fact most of them, grant more than one 4-inch connection on important properties, particularly if that connection can be taken from two streets, or at least at some considerable remove of each connection from the other.

As to the reasonableness of the demands of the insurance people for large fire services and whether it is good water works practice to allow them; the demands of the insurance people are very largely local. There are only two general rules that have any responsible backing in insurance circles, the one expression being with regard to the 4-inch connection, and the other, which is shown in your *Proceedings* at West Baden, as to the matter of private fire services, where it was the sense both of the American Water Works Association and the Fire Protection Association that meters on private fire services should be provided with special relief valves to take not more than 6 per cent of the pressure, which valves would open up in case of need for a heavy fire flow; no expression whatever being made on the subject of the meter itself.

The speaker would dwell a little further on the subject of the demands of fire insurance people, because it has unfortunately made

some bad blood in some cases. There is no reason why our insurance offices cannot be careful of the good of this association as well as that of any association of fire insurance engineers. The fact remains, however, that insurance is divided among different commercial interests, and some of these commercial interests are split up into local divisions, each of which may not have very much knowledge of what the other is doing; and they are also governed more or less by local conditions.

An insurance company in the actual writing of its policies has a choice of four courses; the sprinkler equipment or fire protection apparatus may be used just as they want it, and rated accordingly; or it may be they do not want it, and again it is rated accordingly; it is merely a matter of price; or the policy form may be so drafted as to disclaim responsibility, in the event of fire, for anything that goes wrong with the special fire protection connection; or the company may say nothing at all on the subject, and rely on evidence to be used in case of a subrogation suit if that be necessary in the event of anything going wrong. Now it is a practical impossibility for a water works to know which of these four courses an insurance company in the writing of its policy may take.

As to the control of large private fire services in the cities. This subject is very vague, and there does not seem to be anything very satisfactory as to it. The same thing applies to the proper distance of shutoff from building supplied. Nothing has been reduced to practice and there seems to be no near prospect of it. With regard to inspections and method of making them, that is a matter for each water department to determine for itself; but unquestionably it should have the right of full access to the premises.

Speaking of joint connections to other sources of supply, fire pumps sometimes draw from polluted streams. There is then no question of the danger cf puttiug on fire pump pressure for test purposes or other purposes against ordinary check valves. You gentlemen have been very conscientious in your endeavors to support boards of health in matters of this kind, and you are entirely correct in your demands for soft seated check valves with an indicator cock in between, and regular tests. They are not too much to ask.

As to metering private fire services and danger of interrupted service by reason of having meters on such services, that is very thoroughly covered by the *Proceedings of the New England Water Works Association*, to the effect that meters that have any mechanism what-

ever that will obstruct the free flow are objectionable, for which reason the American Water Works Association and the National Fire Protection Association agreed on the wisdom of having a relief check safety valve, to be used in parallel with the meter.

As to the type of the meter itself, or so far as the meter proper is concerned, the fire protection interests can confine themselves entirely to the question of the efficiency of the safety valve feature. Some of the appliances and safeguards now on the market are satisfactory; others are not. Most of the principal insurance inspection offices on sprinklered risks feel that the amount of water that is stolen is quite easily regulated by seals and inspection. Where fire protection pipes are used for fire protection only and no consumption of water is normally intended, the seals and inspection should be sufficient. Where the same pipes must serve for both domestic use and fire protection, a strong effort should be made to have the domestic service put off by itself and separately metered.

With reference to the charge for fire services, unquestionably there should be a charge. As a matter of practice a charge of $50 a year for a 4-inch connection seems to be a charge that a water works can collect; they seem to be able to get the money. When they go over $50 for a 4-inch connection the objection and resistance seem to run up pretty sharply and the difficulty of the collection increases.

Mr. Wirt J. Wills: You said that a 4-inch connection was satisfactory to most insurance engineers.

Mr. Albert Blauvelt: Yes.

Mr. Wirt J. Wills: This matter was settled in Memphis two or three years ago; but some citizens are writing all over the country trying to ascertain what charges are being made. An application was made for an 8-inch connection from an 8-inch main for premises already having a 6-inch service. Can that be called right and reasonable?

Mr. Albert Blauvelt: Do you want to know if you were right? Yes, sir.

MR. WIRT J. WILLS: As to the charge you said just now that a charge of $50 per annum had proven satisfactory for a 4-inch connection.

MR. ALBERT BLAUVELT: They usually manage to get the money.

MR. WIRT J. WILLS: Do you not think that a charge of $36 for six hundred sprinklers or less on a 4-inch connection is reasonable or equitable, including all inspections?

MR. ALBERT BLAUVELT: The speaker declines to give any opinion on the equity of that charge. You can usually collect $36 easier than you can $50.

MR. WIRT J. WILLS: You said just now that $50 was collectable.

MR. ALBERT BLAUVELT: No, nothing about collecting it, but that they could get $50.

MR. WIRT J. WILLS: Anyway, you agree that for a 4-inch connection furnished by a private company there should be some charge made when the inspection is made and the sealing kept up?

MR. ALBERT BLAUVELT: Absolutely. Consult your *Proceedings* where you will find the speaker has said the same thing for years.

MR. H. P. BOHMANN: In a consideration of the question, is a private fire service one of the proper functions of a water works, the same as the public hydrants, or a valuable and special service rendered to a certain citizen, a service that should be paid for by the one receiving the benefit, the fact must not be lost sight of that the function of a municipality is to provide means for the protection of the health, life and property of its citizens, and in the establishment of these means to provide for an equitable and just administration of the same for the welfare of the entire community.

In the provision of protection against fire loss, we find municipalities constructing and maintaining systems of water service, connecting therewith fire hydrants and fire cisterns, placing them with special regard to the particular fire risks of the city, organizing and maintaining elaborate fire alarm systems and fire departments, open-

ing and improving roads for ease and rapidity of access by the fire department to the various parts of the city, and enacting legislation relative to the proper construction of buildings and their equipment with respect to fire protection. The expense of all these improvements is borne by the community at large for the special benefit of the community as a whole rather than that of the private individual. Having thus provided this system of general protection to life and property, and having provided means whereby additional and special service may be obtained by the individual, the obligation of the community ends.

Of late years, there has arisen a demand on the part of individuals for more elaborate systems of protection in the form of private fire mains and hydrants, hose stand pipes, and automatic sprinkler systems; and in support of an argument for the installation of these systems, or at least part thereof, by the water works or the municipality, the claim is made that this additional protection against fire loss is a direct benefit to the community in the operation of its fire department, and reduction in the damage by water in fires as against those without such protection; and that the loss of employment of the citizens in the particular industry thus protected is greatly reduced. While it must be admitted that in part these claims are reasonable, a very important fact must not be overlooked that the one principal reason for the installation of these private fire systems is that of a mercenary character. It is a well known fact that the insurance rates are based upon the character of the industry; the condition of the buildings; the proximity to public fire hydrants; the general protection offered by the city, relative to water service, fire department efficiency, and the conditions of access along public thoroughfares; and that additional private service means a reduction in rates commensurate with the extent of such private service. In fact, we find that the installation of a modern sprinkler system, costly though it is, is reputed to pay for itself in a few years in the reduction of the insurance rates. Thus while such installations not only benefit the community in some respects, a more striking and immediate benefit is derived by the owner of the premises in the financial saving of rates, and in the freedom from interruption of business by the installations of systems to check incipient fires.

In view, therefore, of the fact that the municipality has provided a general system of fire protection as above stated, and as this additional system is the next to perfection for the personal convenience

and gain of the individual, there seems to be no legitimate reason why it should be considered a proper function of a water works or a municipality to furnish and maintain these private systems.

Inasmuch as it is a very proper function of a city to regulate the construction of a building, with a view of conserving the health and lives of the occupants thereof, it follows that it is a natural function of a municipality to further require appliances in these buildings which may check disasters through fire or other causes. We find in the building clauses of various cities provisions for fire escapes, ample passageways, outward swinging doors, fire check doors and fire walls, for the rapid exit of the occupants in the event of a conflagration, or to prevent the spread of fire from a nearby building to one thus equipped; yet we fail to note any clause for fire prevention by extinguishing an incipient blaze, thus preventing loss of life by panic, as occasioned many times by the presence of smoke or evidence of fire which could and should have been checked in its incipiency.

It should not, therefore, require any great stretch of imagination to see the benefits derived frcm a compulsory installation of special fire protection along the lines of an automatic sprinkler system, not only to the community at large but to the individual in particular, and it should be the duty of the community to insist upon the installation of some class of automatic fire service in all factories, theatres, hotels, halls, and commercial buildings, with possibly some restrictions as to the latter, and that the compulsory installation of such service by the city carry with it some provision for the supervision of these services, not only for their proper installation, but for their maintenance.

Municipalities should make a careful study of the conditions of the buildings, and grant permission for the connection with the mains of services large enough to meet the demands of the building, yet not so large as to be a menace to the general supply of the district. Insurance companies are very insistent on the installation of mains of such size as to almost carry the peak load of the entire system. It seems to be an arbitrary rule on their part, judging from some installations which have come under observation, to accept a standard of fire protection somewhat below the average of American cities.

Inasmuch as the purpose of an automatic sprinkler system is to prevent the spread of fire by checking the incipient blaze, it seems

plausible that a very large stream of water is not necessary for this purpose, and that with the pressure at the city mains of from 40 to 50 pounds, for installation of 250 to 300 sprinkler heads, a 4-inch main from the street would be of ample size. Larger installations should not require a main of greater diameter than 6 inch, or, in a very extensive installation, two 6-inch connections to the mains at different points.

These fire services should be under the control of the municipality by the installation of a gate valve enclosed in a gate valve box at the main in the street. It would seem that this plan of control of a fire main is much better than the placing of an indicator post valve inside the curb line, where it may be subject to damage by carelessness in traffic operations, or to being covered by the falling walls of a building. Inasmuch as the line of the street main is generally 10 to 15 feet or more distant from the curb, danger of covering the gate boxes by falling walls is very remote.

For the control of the branch lines in the building, if outside control is desirable, the distance of the shut-off from the building should not be less than 12 to 20 feet, or as a general rule, approximately one-third the height of the building.

These private fire supplies should be entirely separate and distinct from any building service line. No connections whatever for the domestic supply of the premises should be allowed. This is a very important consideration, especially so in the event of a city having small mains and comparatively low pressure, for the reason that if joint building connections were allowed, the consumption for domestic purposes would materially lower the pressure and service for the automatic fire line, to such an extent perhaps as to impair the efficiency of the latter considerably; and for the purpose of inspection and test of the fire line, the constant use of water for the domestic service would prevent the knowledge of the true condition of the fire service.

Mr. Gorham Dana:[1] The speaker would like permission from the chair to enter into a discussion of the general proposition, because it seems that these questions are all very closely allied, and it is pretty hard to limit one's self to one particular phase of it.

To begin with, to disagree with Mr. Blauvelt on some of the points which he brought up, insurance companies are pretty well agreed

[1]Manager, Underwriters' Bureau, Boston, Mass.

as to what they want in the way of fire service connections. Rules for automatic sprinkler service have been developed after forty years' experience. The present rules have been in print for about ten years. The rules for pipe sizes have not been modified materially for over ten years and are the result of long experience and numerous tests made in the field as to the amount of water which flows through sprinkler systems. The present schedule of pipe sizes is likely to remain as it is for many years. All who are familiar at all with the automatic sprinkler proposition know that the size of pipe to feed an equipment depends upon the number of sprinklers on a floor; it does not make any difference how many stories high the building is. The theory of automatic sprinkler protection is that a fire must be put out on the floor in which it starts. The fire is not likely to spread from floor to floor, because the stairways and elevators and all other openings are supposed to be enclosed to prevent the spread of fire. The size of the riser to feed the sprinklers is exactly the same in a ten story as in a two story building, provided the floor area is the same. Therefore it seems that the proposition of charging per sprinkler head is not correct, because the total number of sprinkler heads does not fix the size of the pipe. Now the rules for automatic sprinklers are well recognized throughout the country and agreed on by practically all insurance interests.

The National Fire Protection Association has been in existence for twenty years. That association was started primarily to codify the sprinkler rules so as to make them uniform in different parts of the country. That was its first proposition. Since then of course it has taken up a great many other subjects; but that was the primary reason why that Association was started. The rules have been slightly modified since, but in the main they are the same. They are agreed to by practically all insurance interests. That being the case it is hardly fair to say that there is very much divergence of opinion among insurance people as to what is wanted in regard to fire protection connections, because the rule is that a certain number of sprinklers on a floor requires a certain size of pipe to feed them. The limit of the 4-inch pipe is eighty sprinkler heads on a floor; but as probably most of you know, one sprinkler head covers on an average 80 square feet to 100 square feet, dependent upon the construction. It may run down to 60 square feet. Where there are 140 sprinkler heads on a floor a 5-inch connection is required. Where there are 200 heads on a floor it requires a 6-inch connection.

These points are so well established by fire insurance interests that it does not seem that they can be disputed.

Private fire service is a proper function of a water works system. It is installed solely to put out fires, and generally speaking should be used only for that purpose. That fires are put out with private appliances, especially automatic sprinklers, with the use of less water than when public hose streams are used, is a well known fact. Statistics of the National Fire Protection Association covering twenty years and 16,680 fires show that the average fire in sprinklered buildings is put out with 6.8 sprinklers. Assuming that each sprinkler delivers 15 gallons, which is believed to be a fair average, the amount of water discharged is 102 gallons per minute. A single standard hose stream delivers 250 gallons per minute.

These statistics are taken from the last annual report of the National Fire Protection Association published this year, and cover the experience of twenty years. They are correct except for the fact that there are a few fires which run over 100 heads per fire, where the data were not given accurately enough.

Now coming to the question as to how long a sprinkler system operates and how long a hose stream operates, it would be a difficult proposition to fix definitely; you will all agree that a sprinkler system is not in operation very much longer than a hose stream in the event of fire, and that the chances are that there will be more than one hose stream used. It is clear that the amount of water used is certainly much less than where hose streams are used.

Mr. Dow R. Gwinn: The speaker's relations with the insurance people have been of a most pleasant character. Mr. Blauvelt understands the business thoroughly, and is very fair indeed, and very willing to listen to the viewpoint of the other fellow.

At Terre Haute we have put the private fire protection problem behind us; it no longer bothers us. Every water works man here should prepare a list of rules covering private fire protection and have them adopted by the proper parties; Terre Haute has a whole page in its book of rules covering private fire protection, as to how it will be furnished, etc. This has been approved by the Public Service Commission of Indiana; so that if a man comes in and wants a connection from the water works for private fire protection, sprinklers, or otherwise, he is referred to the rules.

It is not the function of water works departments or companies

to furnish private fire protection. The functions of a water department or company is to furnish water for public fire protection, and for the use of the citizens. The matter of private fire protection is a matter of contract as between the person wanting that special protection and the company; and the company or department is in the position to specify what those conditions are.

At Terre Haute we furnish service up to the curb free of charge, specifying the size of the service. The rules do not say that there shall not be anything larger than four inches, but that is our policy. We furnish a detector meter at the property line or on the sidewalk. We charge the company or person desiring the service a minimum rate. Our Public Service Commission in passing upon that have specified a double minimum; that is, where the minimum rate for the ordinary 3 inch meter, say, is $3.75 a month, they specify that the minimum rate for a meter in the case of private fire protection shall be $7.50. With a 4-inch meter the ordinary minimum rate is $10, in the case of private fire protection it is $20, for the reason that private fire protection is a valuable service, and that the person receiving the service should pay a fair price for it. We do not furnish private fire service unless the chief of the Fire Department gives his permission; in other words, the water company does not desire to assume all the responsibility of furnishing private fire protection. We put it up to the chief of the Fire Department and let him say whether in his opinion it will be satisfactory to have a large connection to our mains.

We have provision against other sources of supply being connected with our mains. On account of the awful experience in several cases we do not care to take the chance of polluting the public water supply by having it connected with a polluted supply.

Then we have a rule covering guarantees; for instance, the company in no manner guarantees to furnish the proper quantity of water through private fire protection service, nor does it undertake to guarantee anything relative to such service, etc. Our rules go into the matter very thoroughly.

Mr. Ira G. Hoagland: The speaker will point out answers to some of the questions concerning private fire services which are to be found in the proceedings of former meetings of this association, in addition to the few statements he would like to make.

Good answers to the question "Is a private fire service one of the

proper functions of a water works, the same as the public hydrants" are found in what Halford Erickson said in his address, "Rates and Rate Making Under the Wisconsin Public Utility Law", at the 1913 meeting.

In the first part of the address he said: "In many cases the furnishing of water for fire protection is the most important of the two general purposes for which water-supply systems exist". (See p. 52, PROCEEDINGS, 1913).

Mr. Erickson maintained that sprinkler systems or private hydrants "supply a means by which water can more effectively be directed upon a fire at some given point", thereby improving a city's facilities for attacking fire and benefiting whole communities, not particular individuals. (See second paragraph, p. 61, 1913 PROCEEDINGS.)

The reduction of the community's fire risk by private fire service was remarked by Walter Edward Miller, an engineer of the Wisconsin Railroad Commission, in the discussion on experiences with private fire services at the 1912 meeting. (See second paragraph, 375, 1912 PROCEEDINGS.) He described the effect of the operation of automatic sprinklers and said: "It seems fair to assume that the community derives a decided benefit from their existence, through their quick action and consequent reduction of fire loss, both in property and business, and perhaps human life."

"While this class of service has a greater or lesser value to the property owner, it is equally clear that it has some value to the water utility, and to the public in general", said Mr. Miller in his address "Charges for Public Water Service to Private Fire Protection Systems", at the 1913 meeting. (See second paragraph, p. 122, 1913 PROCEEDINGS.)

Mr. Miller pointed out that a water utility should be interested in the prosperity of its patrons, which means the prevention of destruction of industries by fire. When industries are burned the employment of workers, many of them patrons of a utility, is interrupted. He said that the community should be interested "in the preservation and prosperity of its industries, the continued employment of its people and in the protection of property and human life," also "in the cost of carrying fire insurance." Because of the effect of fire losses on insurance rates generally, Mr. Miller held that "the public as well as the individual property owner is financially interested in the installation of better fire protection facilities in the establishments of large value".

To emphasize the fact that the private fire service is not an individual but a community proposition, Mr. Miller remarked the plan of requiring, by municipal ordinances, the protection of certain classes of property by automatic sprinkler systems. This is done in Chicago. He said that this is in the interest of public safety and the time is coming when all of our leading cities will have such requirements in force. "The enactment of ordinances imposing upon property owners a duty of providing expensive private fire apparatus carries with it a moral obligation on the part of the city to furnish water to that apparatus instead of withholding it for use only through city hydrants and fire department service," declared Mr. Miller. (See first paragraph, p. 123, 1913 PROCEEDNGS.)

Continuing he made the following assertions:

Most private fire services are supplied "either entirely without special charge or at a very small charge."

No need of charging for private fire services when there is sufficient income from the public hydrant service furnished.

In commenting on the actual cost of supplying water to private fire services, which Mr. Miller said is very little, he reviewed the economic effect of automatic sprinkler systems, and said: "The furnishing of private fire protection effects a direct saving to the utility from the cost of furnishing only public fire protection service."

A superintendent of a water works says this: "Any legitimate effort to diminish fires should be fostered, particularly by municipally owned plants where the stockholders and the patrons are practically the same parties."

James R. Young, Insurance Commissioner, Raleigh, North Carolina, says: "Some time ago Raleigh, and since that other cities, decided to furnish free water for private fire protection, such as private hydrants, standpipes and automatic sprinklers. Still the good work goes on, and will no doubt continue until every city or town in the state owning its water works will take the same course. This will no doubt be followed in time with a requirement that every business building in the fire district shall be equipped with automatic sprinklers, and this would richly pay the city as well as the owner of the property, not only in the safety from fires, but in greatly reduced fire insurance rates. The cost of putting in an equipment of standpipe or piping is very small to the property owner, and the loss to the city is practically nothing, as no water is used except in case of

a fire, and then much less than would be used by the fire department in putting out a fire."

Private fire protection should not be confined to any one class but should be extended to all classes, in common justice to the community as it has contributed to the establishment of the water utility, and private fire services modify the demands on the utility and thereby favor economical maintenance.

In view of the fact that the average loss per fire in sprinklered properties is 99 per cent less than it is in unsprinklered properties, it is easy to conjecture how beneficial sprinkler protection would be in business buildings, hotels, schools and other non-industrial classes, the fire waste in which is really fearful.

As to the size of service allowed and proportion to size of mains, in his address "Private Fire Protection Service Charges", at the 1913 meeting, Leonard Metcalf remarked the insignificance of the risk from broken private fire service connections and advised against arbitrarily limiting the size of them. (See pps. 131 and 132, 1913 PROCEEDINGS.)

Of 314 replies to a question asked water works men concerning the maximum diameter of private fire service connections, Mr. Metcalf said that 79 per cent specified a maximum, and, of those that did, 76 per cent specified a maximum size of 6 to 12 inches. (See p. 143, 1913 PROCEEDINGS.)

For answer to the question: Are the demands of the insurance people for large fire services reasonable, and is it good water works practice to allow them? (See p. 141, 1913 PROCEEDINGS. Control of Large Private Fire Services.)

In discussing the subject "Direct Connection from City Water Mains to Sprinkler Systems and Standpipes", at the Fortieth Annual Convention of the International Association of Fire Engineers in Denver, Colorado, September 17–20, 1912, F. A. Raymond, an engineer of the National Board of Fire Underwriters, spoke of different arrangements of controlling valves, particularly electrically operated valves controlled from remote points. What Mr. Raymond said is printed in the proceedings of that convention and water works men will find it interesting reading.

Regarding joint connections to other source of supply, the hazard of water contamination in connecting the public water service with other sources of supply to sprinkler systems can be eliminated by using special forms of double check valves, which have been tried out and found reliable.

There would seem to be no more reason for metering private fire services than there would be for metering connections to public hydrants, as water used in extinguishing fires is not charged for. However, there may be need sometimes for some simple form of detecting device in connections to private systems of underground piping, where there are possibilities that water may be taken for other than fire purposes. The by-pass meter used in Seattle, Washingon, is a practical and inexpensive detector meter. But there does not seem to be any need of detecting devices in connections from water mains that go direct to sprinkler systems inside buildings, as the alarm valve in the sprinkler system is in itself a sufficient detecting device. In the discussion on private fire protection at the 1913 meeting A. A. Reimer told of his acceptance of this arrangement and described its effect. (See p. 180, 1913 PROCEEDINGS.) The water department in Washington, D. C., came to the conclusion that the cost of the installation of expensive detector meters was out of all proportion to the actual service performed by the meters and abolished the requirement for them, and now installs the simplest form of small by-pass meter. Different methods of guarding against surreptitious use of water from private fire services were described by Leonard Metcalf at the 1913 meeting, (See pps. 133 and 150, 1913 PROCEEDINGS.) and he suggested that this association be guarded in advocating expensive detector meters, for in a small plant the burden of the installation may defeat the introduction of much desired fire protection service. At the 1911 meeting of the association J. N. Chester said that the complete isolation of sprinkler systems from any use other than that for which they are established and the sealing of all valves in them largely obviates the necessity for any meter in a sprinkler system connection.

A tax paying property owner is entitled to public fire protection. If he puts in a sprinkler system which will control fire with much less water than would be used by the fire department, it does not seem fair to make him pay the community for doing this. Rather it would appear that the community ought to pay him for the improvement. "The speaker's view is that the service furnished to automatic sprinkler systems should be covered by the hydrant rental," said W. E. Miller, at the 1913 meeting. "This is simply allowing the owner of the plant protected by automatic sprinklers an opportunity to make more efficient use of a service which otherwise would be supplied only through hydrant and fire department equipment."

(See second paragraph, p. 186, 1913 PROCEEDINGS.) K. F. Bowman, superintendent of public safety, Bureau of Water and Lighting, Harrisburg, Pennsylvania, says: "We make no charge for water used for sprinkler systems, either in factories or business houses. We feel that the water consumed through a sprinkler is a considerable saving over the water used by a steam engine from plugs for the same purpose. We therefore encourage all factories or large buildings to have a sprinkler system installed, as it is in direct communication with any fire that might occur in that building. For this reason we make no charge for this service."

Leonard Bauer said at the 1912 meeting: "We make no charge for private fire services in Newport, Kentucky, taking the stand that it is not only property that we are protecting but it is human life. It is just as necessary that a municipality should consider the fact that it is protecting human life as it is that it is protecting property; therefore, we furnish water free but they must pay for the installation of the services."

At the 1912 meeting it was reported that Daytona, Florida, made no charge for private fire service. All property is taxed to maintain the fire protection. Fire lines are installed as far as the curb at cost by the city. The water that is used by private fire lines for extinguishing fires would presumably be taken from the city hydrants were there no private fire line. We therefore consider that the private fire line not only costs the city nothing, but that it actually saves expense for the city, the saving resulting from earlier, and therefore better, control of the fire, which results in the use of less water and takes less time from the fire department. The attitude of Daytona is an excellent criterion on this point.

The following extract from an editorial in the Waterbury, Connecticut *Republican*, inspired by several severe fires is interesting, as it shows the effect of onerous charges for sprinkler system connections:

> The best lesson to be learned from our recent experience with fires is that it is costly not to build fireproof structures. The next is that although fires **can** start in fireproof buildings and feed on the contents, they are generally arrested at the start when installing sprinkler systems.
>
> The lack of sprinkler systems is distinctly up to the city and not to the property-owners. This is one of the cities where the property-owner who furnishes his own fire protection has to pay an extra water tax. The water department has a standing charge against sprinkler systems, so much a year for each sprinkler head. A sprinkler head uses no water until there is a fire.

Then it pours on water, until the fire is out, and thereafter until it is discovered and the water turned off.

The city penalizes a sprinkler system almost as though it were continually using water. The reason we have never been able to see. It may have been because the first sprinkler systems were installed by manufacturers and somebody was afraid the manufacturer would get something for nothing unless he were taxed on his sprinklers. Of course, the rate once having been established, it is difficult to remove it, because it brings in a certain amount of revenue and the city needs the money and does not like to cut off any revenue.

So we jog along. The building which has a sprinkler system takes care of its own fires. The building which has no sprinkler system has a little cellar blaze which not being promptly discovered, grows into a big fire. Then the city sends an expensive fire department to pour half a million gallons of water on the blaze and does not charge anybody a cent for it. Water is supplied through a dozen lines of fire hose at high pressure and without charge. When it is supplied through a small hole in a sprinkler head it costs money, and the money has to be paid whether it is used or not.

This discouraging of automatic fire protection is penny wise and pound foolish and ought to be stopped. The city ought to take off the sprinkler head tax and then compel the owner of every important building to sprinkle his buildings, or at all events his cellar.

Mr. W. S. Cramer: Two speakers have made the assertion that there is less water used in the automatic sprinkler system than in a fire fought by a hose stream. Was that true in the Salem fire in the year 1914? Is it not true that there was an entire failure of the water supply there due to the breaking off of an 8-inch and two 6-inch sprinkler connections in the earliest stages of the fire?

Mr. Ira Gould Hoagland: Absolutely no. The reason was that sprinklers were not in the building where the fire started. The breaking of sprinkler system connections did not occur until several hours after the fire started. If you will read the records you will find that they are very clear, and you can easily determine the facts. Full reports of the circumstances of the Salem fire were published by the National Fire Protection Association, Boston, and the National Automatic Sprinkler Association, New York.

Mr. W. S. Cramer: The speaker has as his authority the report of Mr. Frank McInnis of the Boston Water Department and Mr. Clarence Goldsmith of the Boston High Pressure System published September 19, 1914, in the *Engineering Record.* In this report the blame for the extent of the Salem fire is placed on the failure of

the sprinkler connections and every water works official should read this report.

MR. GORHAM DANA: In regard to the Salem fire, the pressure had decreased in the city mains very materially in the early stages of the fire; but as Mr. Hoagland says there were no sprinklers in the building where the fire started, and it was some little time before the fire reached a building where there were sprinklers. The National Board of Fire Underwriters made a test after the fire to learn what was the effect of broken sprinkler mains on the water supply. There were sprinkler mains broken after the fire started, and they made a test with those particular mains open and also closed, and found that the difference was almost unappreciable. The small domestic connections, a great many small ones, not a few large ones, were what really made the trouble.

MR. C. B. SALMON: There is a vast distinction between a municipal plant and a privately owned plant as to the effect of these connections. In a private water works system a large manufacturing plant may locate at a point where they can get side track privileges or in some outlying part of the town where land is cheap and, the district being unsettled, the water mains are not over 6 inch, and they ask you to make a 6-inch connection for a sprinkler service inside their factory which would take all the supply of that water main in case of a fire and leave the balance of the district without water.

If you decline to attach so large an opening they complain to the council that they cannot get fire protection. In the case of a municipal water works they usually work the council through political influence and secure it. The principle in either case is wrong and an injustice upon the public for the reason that their only motive is to save money on their insurance. Why should the public be asked to pay a part of their insurance? Even if the water mains are larger than 6-inch it is dangerous to permit larger than a 4-inch opening from any one street main, as in case of falling walls or floors the interior pipes of a sprinkling system are opened and generally broken off so that the entire capacity of a 4-inch opening is being drawn, and would endanger all the adjoining risks by reducing the fire pressure on the connecting mains.

Mr. W. Z. Smith: As to the function of a water company to furnish private fire protection, it seems that there is no obligation on the part of a water works, whether it be a municipal plant or private company, to furnish private fire protection. The insurance people themselves have already answered that question in that they do not make a general reduction of insurance rates to the city by reason of the fact that a few of the property owners have installed private fire protection. They do not even allow a reduction of rate to the immediately adjoining property. The property directly benefited by private fire protection enjoys all the benefits of the reduced insurance rate; and probably not 1 per cent of the people who now have private fire protection would have installed it had they not been able to get that very favorable reduction in cost.

Why should a municipality or a private water company furnish a valuable service without charge? Why should they be required to lay larger supply mains in the streets to provide this additional protection to private property and be put to that expense without some remuneration therefor? If the entire city received financial benefits in the way of reduced rates by reason of having private fire protection to certain properties, then there would be some reason to say that there was an obligation; but inasmuch as they do not, why should not the man who is receiving the benefit pay for it?

As to the relation between a private fire service and a public hydrant, the speaker cannot see that there is any relation at all between a public fire hydrant that is installed and maintained at the expense of a water company and that of a 4-inch or 6-inch or 8-inch main that goes into somebody's property and protects only that property from immediate damage. The one is a valuable service, enjoyed more by the party immediately protected than by any one else, while the other is a service protecting all alike. If that were not the case the general question of reduced insurance premiums would affect the entire block instead of only the property protected.

Referring to the statement made by one of the speakers, that "sprinklers often go off and by putting out a fire before it gets a headway thereby protect adjoining property", in one particular instance a sprinkler head did go off and put out a fire before it could spread to any other part of the building, and it was not even necessary for the fire company to connect up with the plug when they reached the fire. In another case where there were two 4-inch connections going into the building the fire did gain headway, the

building was destroyed, the walls collapsed, both services were broken off at the property line, and the final result was the destruction of the entire block of property by fire.

Mr. Lawrence Daw: In our rating of cities, in arriving at a base rate, the conflagration hazard and structural conditions of the city have always been considered, and usually amount to about 8 per cent of the total rate. In that conflagration hazard is included the number of sprinklered buildings and the manner in which they act as cutoffs. In other words, the conflagration hazard is mitigated by these sprinklered risks, and they are included in that way as a general reduction of the hazard charge in the basis rating of the whole city.

The speaker would like to answer another question that Mr. Smith brought out, that nobody except the owner gains any benefit by the installation of sprinklers, that the neighboring rates are not reduced. He may be correct in that they are not reduced, but only in a technical way. On any adjoining or neighboring buildings a charge is made for the exposure risk. Take an ordinary mercantile block, if there is a sprinklered building between two others we make a nominal charge on the exposed unsprinklered mercantile building for the presence of that sprinklered risk, whereas under ordinary conditions that charge would run anywhere from twenty-five to fifty cents per hundred where the central building is not sprinklered.

Now Mr. Smith raised one other point, with reference to providing extra sized mains for a private fire protection service or sprinklers. We find in hydraulic tests of a large number of cities and towns that, if the mains originally laid are of sufficient size to provide for proper outside hydrant fire protection, with a proper additional allowance for taking off ordinary service connections, there is no difficulty in getting water enough to provide for automatic sprinkler connections.

Mr. Gorham Dana: The speaker would like to answer one other point that Mr. Smith brought up, of the isolated case where two 4-inch connections were broken. That is an exceptional case. You will admit that it is not very often that two 4-inch connections in a sprinkler system are broken. Statistics show that the average number of sprinklers opened on a fire is less than seven. It is not

very likely that where all the sprinkler heads are open there is much breaking of pipes. While there may be found cases going to one extreme, there are also cases going to the other extreme where only one sprinkler is opened and where the flow of water is very small. In neither case is there any argument furnished against the general proposition.

Another point is the relation between public and private hydrants. It would seem that a sprinkler system or private hydrant system is simply an extension of the public mains to do a service more efficiently than if done in any other manner. That is, when you have a fire and use the public hydrants you use a large number of hose streams and a large amount of water to put out the fire. When you have a sprinkler system you get the same effect with the expenditure of much less water. Is it not a benefit to the community, and also to the water company, to extinguish the fire with less water than would be necessary otherwise? Both the sprinkler system and the public hydrant system are put in to accomplish the same purpose, and there is no more reason for a charge for private fire protection, that is rental, than for public hydrants. There is a reason for charging for the cost of installation; but so far as rental is concerned, the speaker sees no difference between a sprinkler and a public hydrant system. You certainly would not charge a man for public hydrant protection; and if he puts in sprinklers at a considerable cost to himself so that the fire is extinguished with less water, why should he be taxed for so doing?

Of course the argument is made that he makes a saving in insurance. That is very true, but that is entirely up to him. He has to make an investment; it costs him a lot of money to put in that sprinkler equipment. If he were to put that same money into another investment he could make perhaps 10 per cent return. Why should the water company tax him for so doing, especially in view of the fact that it is a benefit to the community in that less water will be required if a fire does come?

Mr. W. Z. Smith: Is it not a fact that where hydrants are placed inside of private property you allow a better rate than you do for hydrants on the street immediately in front of that property?

Mr. Gorham Dana: Not if the building is properly protected with public hydrants. You cannot protect a large mill property

with hydrants on the street; you cannot get the hydrants near enough; but if the hydrants are within a proper distance from the building the rate is the same, whether they are public or private.

Mr. Patrick Gear: At Holyoke there is a 6-inch connection, taken off an 8-inch pipe in a street, into a building that is sprinklered. The insurance people demand another connection into that building. The owner of the building came to see about it, and was told that there was a 12-inch pipe in the other street, and if he would take his connection off of that pipe his building would be always protected, because those two streets would never be both shut out at the same time. That was satisfactory to him, but the insurance men inspected it and decided that it wasn't the thing to do.

Mr. Lyman P. Hapgood: The speaker holds no brief for the National Board of Fire Underwriters, but would like to say as a matter of fair play that in Jamestown we have had quite a lot of dealings with the National Board, and so far have never had any trouble; and further than that, we have acted together, that is the water department and the representatives of the National Board of Fire Underwriters have met half way, and as the result the city has recently received a reduction in its insurance rates.

Mr. D. R. Gwinn: In reply to the question asked by the representative of the insurance interests as to why a charge should be made for private fire services, it seems to the speaker that it resolves itself down to readiness to serve. The ordinary house is supplied with a $\frac{5}{8}$ or $\frac{3}{4}$-inch supply pipe; but when a man wants private fire protection he must have something a great deal larger than that. If he is charged the minimum rate of 60 cents on the basis of a $\frac{5}{8}$-inch service pipe, then he should pay a minimum rate in proportion to the amount of water that he can draw from the mains; because the works in the case of a direct pressure plant must provide pumps, filters, settling basins, and mains large enough to take care of this service. Now the department or company that supplies such special service should be paid in proportion to what an ordinary householder pays for the ordinary service pipe. Private fire protection is a valuable service and should be paid for, there is no doubt about that.

Then upon the question as to the difference between the public hydrant and the automatic sprinkler pipe, the conditions are en-

tirely different. A 6-inch line running up to the curb line and out of the way of traffic is a perfectly safe proposition from a water works standpoint; but when you run a 6-inch or 4-inch pipe into a three or six story building, and have a number of stand pipes running from it that are liable to be broken off in case the sprinklers do not put out the fire, then that is a different proposition entirely. We have had in our own city one large factory burn because the automatic sprinkler did not extinguish the fire, and a 6-inch connection was broken off. Some one may say, "Why didn't you shut off the valve?" The reason was that the wall fell outwardly and covered the valve, and in the meantime the pressure dropped from the ordinary fire pressure down to such a low point that it was practically useless for fire service. If at that time a serious fire had broken out in the business district we would have had a conflagration. There is no doubt about it. It would have been an impossibility to have furnished proper fire protection.

The speaker believes the time will come when the insurance people will say, "Do not allow a 6-inch connection made with your mains, because there is more necessity for maintaining general fire protection than the fire protection of a single building." The automatic sprinkler is a special privilege for those who can afford to pay for it. The man who has to depend on a small hose does not get the same benefit that the sprinklered factory man does; and when the latter gets that privilege he should pay for it liberally; and the water department should be provided with all kinds of protection in the way of valves, meters, and all that sort of thing.

Mr. Albert Blauvelt: The speaker has noticed in this discussion that there have been a considerable number of allusions made to a point that is not at all covered by this question, and that is the amount of water that is used at the time of the fire. Is that pertinent to this discussion and do water works men usually take that matter into consideration at all, do they consider it worth while?

Mr. Dow R. Gwinn: The amount of water used for extinguishing fires is such a small quantity that it is hardly worth taking into consideration. The main thing is in being ready to serve water. In Terre Haute a record is kept of all the fire alarms and the increased consumption during the time that the fire pressure is on.

It is a very small portion of the time, and represents a very small portion of the amount of water actually used. It is the being ready to serve the water that costs the money; it is not the water itself.

Mr. Henry P. Bohmann: The statement was made by one of the speakers that the average number of sprinkler heads that went off is less than seven. The speaker is very much interested to know what the maximum number was if he can get that information, and what size pipe would be required to furnish the necessary water for the maximum number.

Mr. Gorham Dana: In reply to the last question the speaker would state that he mentioned that there was no way of tabulating the figures exactly, but that the National Sprinkler rules, based on forty years' experience and numerous tests, require a 4-inch pipe to feed 80 sprinkler heads on a floor, a 5-inch pipe to feed 140 sprinkler heads on a floor, and a 6-inch pipe for 200 sprinkler heads on a floor; and certainly there is no case where a 6-inch pipe would not have fed that number properly.

One point in regard to Mr. Gwinn's argument that being ready to serve is what you pay for, the speaker submits that if you give them public hydrant protection it is going to cost you just as much to be ready to serve that as it is to be ready to give them sprinkler service which will be ready to put out fires with less water.

Mr. Nicholas S. Hill, Jr.: Antecedent to a proper appreciation of a fair charge for fire service, it is necessary clearly and definitely to understand the principles involved in the cost of service and the elements which are included in that cost.

Every water company, in fact every public service company, supplying similar service finds its service divided into three classes. There are demand or capacity costs; that is, those costs which do not vary with the quantity of the commodity furnished, but which vary more nearly with the demand which a consumer may make, or, as Mr. Gwinn has put it, the "readiness to serve".

Every water works plant has an average daily load. If the plant could be designed for an average daily load and for that only, then the investment in it would be much smaller than it must be to meet the demand which the company has contracted to supply at the peak load, or, for example, when it makes a connection for a pri-

vate fire service. These capacity or demand costs may be summed up under the generic term of "readiness to serve", but these costs are separate and distinct costs, and may be shown by analysis to be separate and distinct from those costs which vary in proportion to the quantity of the commodity served, as well as from the service cost.

The service or customer costs pertain entirely to the individual consumer, such as collecting bills, repairing meters and services, and all that service which is incident to the customer and which would not exist if there were no custcmers on the system. The capacity and service costs may be termed static costs since they do not vary with the quantity of water consumed. Finally, we have the output or production costs which vary with the output of the product and which depend entirely upon the quantity of the commodity consumed, and since these costs vary in proportion to the output, they may be termed the kinetic costs.

Now, so far as fire service costs are concerned, they are almost exclusively static costs, or readiness to serve costs. The proposition of fire service charges, therefore, seems no different from that in any other system of charges. Now, it is undoubtedly true that it is not the water taker necessarily who benefits by the fire service, but it is the taxpayer, and the fire service costs should be paid from the tax levy since property as a whole throughout the city benefits by fire service whether the individual is a water taker or not.

Now, we come to the point of special service. In addition to the general fire service furnished from the tax levy, John Smith desires something more for his own protection, just as an individual may desire to pay a special watchman. He is not satisfied with the public fire service supplied by the city and paid for through taxation. He finds that by providing additional fire service his insurance is lowered and, therefore, he effects an economy by increasing his fire protection beyond the point to which the taxpayers in general may be reasonably assessed. John does not furnish this additional fire protection for himself from philanthropic motives, for the purpose of protecting his neighbor, or some other property. Now, under these conditions, the individual who requires the special service should be willing to pay for that special service, as much as the man who wants additional police protection is willing to pay for a special watchman, or the man who steps into a Pullman and is not willing to ride in an ordinary seat pays extra fare for the drawing room or any special privilege which he enjoys.

It seems a tremendous fallacy to talk about individual fire service being for the benefit of the community. Of course, individual fire service is a benefit to the community as it reduces a particular hazard. So is the special watchman a benefit to the general community because he increases the difficulties of the highwayman, but you may as well say that a man who builds a large hotel and helps the community generally by so doing should have his electric and water service free because he helps the community. You could put up a dozen arguments of a similar kind, and the whole question would resolve itself into one of paternalism under which the taxpayers would supply everybody free who helped anybody else in order to help the community along.

Now, if you will bear these basic principles in mind, the whole question will simplify itself in the minds of everybody. Remember the fact that there are two distinct kinds of service: the proportional service, which varies with the quantity of water supplied, and for which a man should pay according to the amount of the commodity supplied. In addition there is the static service which includes the customer or service cost and the capacity and demand cost, where a man may not use water three months out of the year but would like to have it there if he wants to use it all the year or whenever he pleases, whether it be 1,000,000 or 10,000,000 gallons a day and the company contracts to give him that water on demand. Extra piping and larger pumping engines and other equipment are required to meet this demand cost which, as explained, is a static cost and has no relation to the quantity of water pumped. In the case of the individual it is a special service in addition to that furnished him through the general assessment upon his property.

Mr. W. E. Miller: The courts have had occasion to pass on this question of rates for private fire protection services. They have held the opinion that it is a valuable service, and that the water department or water company furnishing it is entitled to compensation for the service rendered; but any one who gets into the questions of analyses of expenses and determinations of rates, for all consumers of all classes, is up against the question of determining how much of these expenses are properly chargeable to the special fire protection service.

It is difficult to see a logical basis upon which the static or fixed charges can be subdivided between the hydrant, or general fire pro-

tection service, and the special fire protection service; because the hydrant service, if adequate, requires fully as large an investment before taking on private fire protection service as it does afterwards, assuming that the property owner getting the privilege of fire protection service pays for the connection in from the mains. If the static charges of the water works are covered in the rates for hydrant and general commercial service, there is no part of that that can properly be included in the charge for the special fire protection service.

Going to the output expenses or proportional costs, there is less of an element to be included in the charge for private fire protection service than would be involved in taking care of fires in the same premises through the ordinary means, that is, hose streams. So it seems, to get down to the question of the consumer costs, a charge that will cover the expense of inspection and general overseeing of this private fire protection service, where inspection is necessitated by the absence of meters. There should be some charge, but it seems that it must in general be limited to a share of the consumer expense.

Mr. Wirt J. Wills: If the inspection of private fire services alone entails a salary cost to the department of $2500 a year, what rate would be right for the fire protection charge, how much over the actual salary paid for the inspection given? You admitted that there ought to be some charge for the inspection, did you not?

Mr. W. E. Miller: Yes, where the service is not metered and inspection is necessary.

Mr. Wirt J. Wills: If $2500 has been expended for salary alone in the inspection of private fire services, how much in excess of that do you think the water department ought to get back? Do you think that they ought only get $2500, or do you think, they should get more? What do you think is a fair return?

Mr. W. E. Miller: They ought to get the full cost of inspection.

Mr. Wirt J. Wills: Only that?

Mr. W. E. Miller: As a minimum. There would probably be some additional charges, properly assessable against that service.

Mr. Wirt J. Wills: Don't you think there ought to be something more than the actual cold cash salary of the man who did that work and nothing else?

Mr. W. E. Miller: Oh, yes, the plant is entitled to collect from its patrons the total of its proper costs of furnishing all service rendered, including depreciation and a fair return on the value of the property.

Mr. Chester R. McFarland: The charge for this service is not a thing that can be worked out by any fixed rule of thumb. Each property owner must pay the charge proper for him to pay, depending on the conditions surrounding the operation of the plant. In the first place, the general community may be receiving this special fire protection for practically nothing, because the fire hazard is covered by the annual charge for fire hydrant rental, which is sufficient to pay a return on the increased investment necessary to provide a plant large enough to take care of the requirements for public fire hydrants and private connections for fire purposes; but if this is not provided for in fire hydrant rentals or charges, then the man that gets special service to provide against a special hazard, should pay for this service a reasonable part of the return on the increased investment necessary to provide him with this extra service; this charge to be in excess of the regular tax levy which is supposed to cover the fixed or static charges, but if the tax lavy is sufficient to take care of the entire investment for fire hazard, then he has therein borne his proportion of the charges by the taxes assessed on his valuation and should therefore not be compelled to pay any additional charge.

Mr. H. F. Dunham: From the viewpoint of the city the hydrant service and the special fire service cannot be the same. The hydrant service is provided and maintained for the entire community or the city at large and whether such service is contracted or not the responsibility for maintaining it intact rests chiefly with the city. Special fire service is primarily for the benefit of some individual or company and often imposes extra risks of failure of the general service at points far away as well as near by. The hydrant service is from a distribution system laid in the streets and properly safe-guarded. The special fire service is on private ground

where no one can tell what may happen. "Special service" piles have been driven through such private supply mains in one part of a city while the general obligation to maintain fire pressure remained in full force.

No one can read the report on the Salem fire in the *Journal of Engineering News* without getting a good idea of what happened there. Similar conditions and results have been noted time and again. It is beside the mark to say what would or would not occur if more buildings were supplied with automatic extinguishers. We know the chance of failure of distribution systems must be increased by such special connections, and it is reasonable to hold that the risk shall be no greater than is required by good practice. The uses are unlike; troublesome adjustments cannot be avoided.

Mr. Ira Gould Hoagland: There seems to be a tendency in this matter to exaggerate the so-called sprinkler failures, which is not borne out by facts.

Mr. W. Z. Smith: Can a municipality confine its fire service equipment to factories or commercial houses only, if any other property owners should make application for such service? In that case could not the point be raised very reasonably that you were discriminating between property owners who all paid alike their proportion of the taxes?

Mr. C. B. Salmon: At least five public service commissions have decided that there can be no discrimination in either rate or service as between different like classes of service. If a city or private water works establish a rule that they will give factories and commercial houses the privilege of large fire pipe connections for the purpose of reducing fire insurance to those properties; then any hotel, school house, hospital, boarding house, or large store or dwelling, may ask for the same service and demand such a connection upon complying with the rules governing such service. If these large connections were quite generally used in a congested district and a conflagration got under way in that district the water would have to be shut off of those blocks or the fire pressure could not be sustained and the fire would spread still farther. The question is one of private profit, and should be paid by the party benefited, and such a charge made as would not make it profitable for smaller

properties to demand it. If special fire service or sprinkler service is not charged to the property benefited, but paid for by the city, the general fire service will be endangered by too many such attachments.

President Hill: Did you say that five public service commissions have passed upon this question?

Mr. C. B. Salmon: The public service commissions of Wisconsin, Indiana, Missouri, Idaho, Oklahoma and California rule that no such discrimination will be allowed.

Mr. Lawrence Daw: The speaker thinks personally as an engineer, that the question of the size of a branch fire service is one simply of hydraulics; that it all depends upon the available head and the allowable friction loss that you have in getting the water into the building, after determining the amount of water which will be necessary for the operation of the equipment. You have to provide proper sized pipe for the quantity of water; and the size of any one pipe must be such as not to endanger crippling the outside equipment, taking into consideration the location of the risk, and the gating of the water system in the vicinity. That may be laid down as a general proposition. You must of necessity reduce the size and provide two or more connections if it will otherwise in case of a break of the service cripple the entire water system. It is difficult to lay down any hard and fast rule as to the size of connections necessary to provide adequate water for the fire service, but you must not cripple the general system, which can be obviated by proper gating of the latter. A 4-inch connection would of course be the least that should be permitted for a sprinkler equipment.

Mr. Albert Blauvelt: In connection with these remarks the speaker does not think that the Fire Protection Association is very far off in holding pretty much the same view under the sprinkler rules. Attention has been called to the fact that the sprinkler rules contain an absolute requirement for a 6-inch pipe. The reason that a 6-inch pipe is necessary under the sprinkler rules is because very many sprinkler equipments are supplied which meet what is called the standard, that is, that there shall be two sources of supply; and the typical equipment is one with a gravity tank

and a fire pump, or city water connection. Now gravity tanks do not vary very much in their head. The head sometimes is as low as 15 feet, and sometimes as high as 50 feet; and a 6-inch pipe is necessary to hold down the friction loss from the gravity tank to the sprinkler proper. There is no question that for internal piping purposes a 6-inch provision is very wise. That, however, has no relation to the size of the city connections. The city connection is very frequently of a much higher pressure than the pressure afforded by the gravity tank. You gentlemen do not need to be told that the higher the pressure the greater the volume of water that will be supplied through the pipe, so that the effect will be relatively the same as through a larger pipe on lower pressure. The fact that city pressures are so frequently higher than tank pressures is the reason that the sprinkler rules do not make any positive requirements for anything larger than a 4-inch pipe. That does not say that a 4-inch pipe is adequate in all cases. In some cases a multiplicity of 4-inch connections is undoubtedly advisable. Such cases, however, are not so very frequent. We must bear in mind that a 4-inch connection will take all the service pressure that the water works can possibly furnish in many cases; and as soon as the fire department arrives that is taken away, so that you really come back to dependence upon your gravity tank.

Mr. C. W. Schiedel: The speaker has a request for an 8-inch connection off a 10-inch main, and would like advice as to the propriety of granting it. The principal main from the pumping station is only a 12-inch, but the one on the particular street referred to is 10 inches, and the request is for an 8-inch connection off of that. Now what should we really give them; an 8-inch, or how much less? The distance from the main to the building is probably 25 feet.

Mr. William W. Brush: It may be interesting to tell you very briefly the New York practice as to size of connections, etc. We do not allow a cut on a main of a size equal to the diameter of the main, except that we will take a 6-inch branch off a 6-inch main if it is necessary to furnish adequate supply for a building, but in that case we plan later to reënforce the system so that we will have a larger main in that particular street. This rule has worked out satisfactorily.

One of the previous speakers referred to the necessity of having a sufficient amount of capacity to give the volume of water required to control the fire, and a sufficient volume of water to properly supply the building or group of buildings that asks for protection. Our problem is very different from that of a smaller system, because we always have an ample supply of water available at the reservoir, and we have only to consider the question of the main to carry it to the particular point where it may be needed. On a 12-inch main we take off an 8-inch connection. We do not use any 10-inch connections. On an 8-inch we take off a 6-inch connection, or smaller. No answer can be given directly as to the size that can be taken off a 10-inch main on a system supplied by a 12-inch main; it would depend upon the requirements of the individual building or group of buildings that asked for the connection; but in general an 8-inch connection would certainly seem to be a very large one in a system supplied by a 12-inch main.

There has been a great deal of discussion as to whether there should or should not be payment made for service rendered for fire protection. In New York there is no charge made. A meter is placed on the main and the water used is charged for, which results in almost no payment for the connection. It would seem to the speaker that a charge is proper. A private fire protection system is similar to a private watchman, and the city hydrant is similar to the city police force. No community would think of paying for a private watchman for any plant or commercial house; but they would provide police protection to the community at large to the extent that it was considered necessary through the general police force. There is great difficulty in determining what is a reasonable charge to any individual for any private fire service, based upon the cost of furnishing such service. That problem is one that New York City has not yet undertaken to solve, but it will probably have to undertake it in the very near future. Discussions such as we have had at this meeting are certainly helpful to us, and no doubt are helpful to many others who have a similar problem to deal with.

Mr. C. W. Schiedel: We charge $25 for a 6-inch fire protection connection or smaller, but what size pipe should we allow taken off with reference to maintaining safety for the rest of the system, 6-inch or 4-inch?

Mr. Anthony Keils: How many openings can be taken off a 6-inch pipe? In Mt. Clemens, Michigan, we connected a 6-inch to a 6-inch running off the main street under a building. There were 174 $\frac{3}{8}$-inch openings off that. Normally we carry 65 pounds pressure and from that anywhere up to 125 or 150. A fire a short time ago in one of the Hill apartments was entirely extinguished before the fire department got there, and we knew nothing of it at the pumping station at all. So that that would indicate that so far as the size of the main is concerned, it had no effect on the working of the pumps or the amount of water.

Mr. Leonard Metcalf: The speaker had not intended to say anything on this question because he had already expressed his opinion at previous meetings of this Association, and of the New England Water Works Association. At the same time it seems well to say a word of caution lest conditions in New York be assumed as applicable to those in small communities. There is good reason for the position which has been taken in New York with its congested conditions, high value district, and a pipe distribution system which is totally different from that which prevails in the ordinary smaller city, or the small towns in this country. After all, the question is one of public policy in which is concerned not only the safety of the individual but of the entire community.

In general, for the smaller communities, it would seem safer to limit the size of the pipe connections to 4 inches or there abouts; on the other hand, every situation should be met frankly on its merits. To put an 8-inch connection on a system having a 10-inch pipe in front of a lot, with a 12-inch pipe leading from the pumping station, looks like a very dangerous proceeding. Not knowing all the circumstances, because unfamiliar with the system and reservoir connections, or the size of the distribution pipes, in general it would seem a wise rule to multiply the number of connections, rather than to increase the size of the connections.

Now it is conceivable that on a pipe system of a small community you might with far greater safety take a 6-inch pipe or even an 8-inch pipe at the extremity of the system, on the outskirts of the town, at the opposite end of the pipe system from the pumping station, than you could make the same connection in the heart of the community. Why? Simply because you will maintain under those conditions a higher pressure on the rest of the system than

you would if it were taken in the center of the town. The volume of water, if more than that which could be safely supplied by a 4-inch pipe needed in the case mentioned, can be gotten probably by an additional 4-inch connection from another main. It is certainly safer from the community point of view to have two 4-inch connections coming from different mains than it is to have one 6-inch connection or one 8-inch connection from a main pipe line. While that may involve somewhat greater cost to the insured, it seems to be a cost which the community may well demand shall be incurred in order to make the position of the community a somewhat safer one.

Mr. Gorham Dana: One point that might be brought up to advantage is the variety of conditions in different places; if you have a 6-inch pipe going into a congested district, where there is no chance for outside valves being put within a safe distance, you have a much more dangerous proposition, from a water works' standpoint, than where you have a large yard system where there can be outside valves placed at points accessible at all times. For instance, in a yard with a lot of private hydrants and sprinkler connections, with a post valve located at the entrance of the yard 50 feet from any building, a 6-inch connection in that case is safe from that standpoint, while it might not be safe in another; so that it should not be a hard and fast rule to limit the connection to 4 inches in all cases. Another feature worth considering, if you do not provide adequate sprinkler connection and size of pipe, a sprinkler system is liable to fall down when most needed; and then the sprinklers will not control the fire, you will have to use hose streams, and you will bleed your system a good deal more than if you gave the sprinklers the proper sized connection in the first place.

Mr. H. F. Dunham: Reference has been made to the solution of hydraulic problems as a basis for insurance decisions. Many present will agree with the speaker that such decisions are often without relation to the principles of hydraulics. That is one great source of trouble. It is claimed that a few sprinkler heads will extinguish a fire, but the demand is for connections large enough in many cases to cripple a water supply in the event of breakage.

Concrete illustrations are always being quoted and fill up the journal. A number of factory buildings were supplied with sprin-

klers all on one property that covered an area between two streets nearly half a mile apart. Eight-inch connections were first demanded for the 8-inch protecting system but 6-inch connections were accepted. Near the middle of the property and the connecting system of pipes the conditions were favorable for an 8-inch valve to be kept closed except in some emergency. The installation on either side taken by itself was perfectly satisfactory and "standard" and this was pointed out. But the valve question had to go to headquarters, New York, Chicago, or somewhere, and the order came back "Valve out or no rate reduction" quite regardless of the fact that the risk from two 6-inch connections instead of one had been needlessly imposed upon the city distribution system; upon which contracts and all sprinkler properties had to depend. Arbitrary rather than hydraulic would seem to be the term applied.

Mr. Nicholas S. Hill, Jr.: In that connection, it seems that that is a very good illustration of a capacity charge. Here is a company that has a 12-inch main from the pumping station and a 10-inch distributing main. Some one comes along and makes a request for an 8-inch service pipe. The speaker does not remember the exact ratio between an 8-inch and a 10-inch main, but should say that a 10-inch main is equal to two 8-inch mains, so that such an installation would call for a readiness to serve of 50 per cent of the capacity of the plant. This pipe may run two or three years and never be called into service at all, never bring any revenue; but in order to be ready for it the water department must put in larger pumps, and larger supply mains from the pumping station. The party making that demand can do one of two things; he can lessen the demand by putting in a larger tank, keeping that tank full, and thereby saving the readiness to serve cost to the water works; or if they insist upon an 8-inch connection you can see what the cost involved to the corporation is for supplying the service. The practical solution of it would be to ask the customer if he could not do with a smaller service, and provide a larger tank; because after all, what is wanted is an available supply of water at the initial time of the fire; and a larger tank under those conditions would serve nearly the same purpose.

Mr. John H. Derby:[2] The speaker is employed by property owners to look after their interests relative to fire prevention; and he is

[2]Fire Prevention Engineer, New York City.

brought into contact with both public and private water companies and insurance interests. It is his purpose to serve these interests so that the net result will be equitable to all concerned. A desire to coöperate with the water companies has aided greatly in getting fair rulings for property owners. In this discussion there is one point which is worthy of consideration, that is, that a water company has a mutual interest with the property owner, for the reason that if a city or town is destroyed by a conflagration the water company loses a large part of its income for a considerable time. If a mutual interest is taken by all concerned, an equitable understanding between property owners, insurance companies and water companies can be arrived at.

The subject of metering fire service mains has been one to which the speaker has given some twenty years' thought with the result that he does not consider it fair for a publicly owned water company to require the installation of expensive meters in all cases. Where a connection is taken directly from a street main into a building, there being no yard hydrant system, a channel-seated check valve, having a ½-inch meter connected to the channel space, will indicate whether or not the check has lifted from its seat, thereby indicating that water has flowed in the fire service connection. The small meter dials indicate the flow in hours and minutes. By this arrangement the water works will have a positive indication that water has been taken from the fire service connection. These connections should be made with the understanding that no water whatsoever will be used except for fire extinguishing or tests. The tests can be made in the presence of an authorized representative of the water company, and due credit be allowed the property owner for the water used, which would not amount to nearly as much as the flushing of a street hydrant. If the check valve lifts from its seat an alarm is immediately given by means of a water rotary gong and an electric connection, so the property owner cannot make excuses if the small detecting meter shows that water has passed through it. It would be fair to require the property owner to pay the cost of inspection. If this suggestion were universally adopted property owners and water companies would be saved a considerable amount of money and their interests be protected. Of course the cost of the connection from the street main to the inside of the building should be paid by the property owner. In the case of a privately owned water company, they should be reim-

bursed by the city or town, as the case may be, at the same rate that a connection to a hydrant is charged for. As mentioned before the water company has a mutual interest with the property owner to keep property intact.

Some years ago the speaker was assigned to the duty of testing sprinkler systems in the city of Boston. The water department assigned an inspector to go along to see that an undue amount of water was not used. After the tests the valves were resealed. Probably from 100 to 500 gallons of water were used in these tests.

As to the size of street connections, that would seem to depend upon local conditions entirely, and no one standard can be made. It is a matter of common sense to determine what is right. It is the speaker's opinion that no connection smaller than 4 inches should be made for fire service.

Mr. W. Z. Smith: What are the requirements of the insurance people with reference to the pressure and flow test on the wet side of a dry system?

Mr. John H. Derby: In answer to that the speaker does not know that there is any definite requirements on that subject. A dry pipe valve should be tested at least once a year. The amount of water used in ordinary systems runs from 250 to 500 gallons.

About two years before the Edison plant in East Orange, New Jersey, burned the speaker laid out an equipment of automatic sprinklers and necessary water supplies, which would have cost approximately $50,000. As the buildings were largely of reinforced concrete the Edison people did not consider it advisable to spend the money. In fact, they considered it impossible to have a serious fire. If the true figures were known they would probably show that $4,000,000 worth of property was destroyed and several thousand employees thrown out of work; some for a long time; others were obliged to move away from Orange as they could not wait until the plant was rebuilt. The East Orange Water Department was a loser by this fire.

This whole question of fire service connections, meters and charges should be solved, not by partisans of either insurance or water works interests, but all interested parties should appoint a committee of intelligent people, not theorists, to draw up some reasonable rules and regulations that would be fair to all concerned.

Mr. M. L. Worrell: This reopens a subject that has been "cussed" and discussed until it has been worn threadbare. In municipally owned plants it may become a live political wire, to be used by the politicians for the supposed benefit of the dear "peepul" either to favor or not to favor the insurance companies and those protected. The writer recognizes many good points in favor of free fire service for private property, i.e., for sprinkler heads and hydrants located on private premises for the protection of same; but it is not his intention to take either side in the controversy that a discussion of the subject is sure to bring about. The object is to tell you how free fire service for private fire protection is provided at Meridian, Mississippi; and in order to do this briefly attention is called to the Meridian rules and regulations for such services.

Rule 43. There shall be no charge for private fire protection where no water is consumed, provided the person, firm or corporation receiving such private fire protection shall comply with the following stipulations for the service, namely;

First. A written application therefor shall be filed by the person, firm or corporation to be protected, on a blank form to be furnished by the water department.

Second. A meter, to be paid for by the owner or occupant of the premises, shall be installed on each pipe line leading from the street main to the property protected. The meter shall be furnished and set by the water department at net cost for meter, labor and materials used in setting the same. Sole and unconditional control of all fire protection meters shall be vested in the water department of the city of Meridian. The cost of all repairs and renewals shall be paid for by the owner or occupant of the premises protected, but shall be done by the water department at actual cost of labor and materials.

Third. No fixtures, except automatic sprinklers, fire hydrants or hose connections for fire use only, shall be connected to fire protection line.

Fourth. All water passing through the meter shall be paid for by the owner or occupant at the rates prescribed in these rules and regulations.

Fifth. No water service pipe shall be connected to fire protection lines, nor shall any water be used or taken therefrom for any purpose whatever, except for fire protection.

Sixth. Any person who shall violate any of the foregoing provisions of this rule, shall, on conviction thereof, before the mayor or police justice, be fined in any sum not exceeding fifty dollars, and shall forfeit the right or privilege of free fire protection granted by this rule, in which event such protection shall be withdrawn and the water turned off.

Rule 44. All persons, firms and corporations now and heretofore enjoying the privilege of private fire protection, who shall fail, neglect or refuse to avail themselves of the privilege or benefits provided for by Rule 43, shall continue to pay therefor at the rates heretofore provided, namely:

For each standard single or double nozzle hydrant $25 per annum.

For each hose connection smaller than standard, $10 per annum. But no rate less than $25 per annum.

For each sprinkler head five cents per annum. No charge however to be less than $25 per annum.

MERIDIAN, MISS., January...., 1916.

To the City of Meridian Water Department:

The undersigned hereby makes application for the installation of a system of private fire protection pursuant to Rule 43 for the government of the water department of the city of Meridian as amended by ordinance passed by the council and approved by the mayor on the 15th day of December, 1914, and do hereby agree to abide by the terms and provisions of said rule.

The premises to be supplied with such private fire protection are located as follows:

....

....

Respectfully submitted,

....

....

Approved,

....

Superintendent Water Works and Public Property.

Not one of the private fire protected consumers has applied for "free" private fire protection, yet who can rightly say that this is an unjust rule or regulation?

MR. CLARENCE GOLDSMITH:[3] This question of supplying private fire service equipment is one to which we have given much thought in the past few years, attempting to give fair consideration to all its phases. There is no definite statement on this subject in the National Board's regulations on sprinkler equipments, but a set of rules were drawn up in 1910 by a committee of the National Fire Protective Association. These rules were adopted as standard and, it is believed, offer a reasonable solution of the problem. We do not believe that a limiting of the size of the connection is the best

[3] Engineer, National Board of Fire Underwriters.

course, or even a good course, to pursue, but rather that every reasonable precaution should be taken to ensure proper control of the service in emergency. We have no doubt that in some cases a larger connection is demanded than is required for satisfactory service, and believe that this practice should be severely discouraged.

The rules are as follows:

NATIONAL FIRE PROTECTION ASSOCIATION RULES FOR SIZE AND ARRANGEMENT OF SERVICE CONNECTIONS FROM PUBLIC WATER SUPPLIES TO PRIVATE FIRE SYSTEMS

CITY RISKS

1. Four-inch service connections to be used for smaller equipment, where this size of pipe will furnish ample water for the equipment.

2. Six-inch connections to be permitted where the size of the equipment requires more water than a 4-inch can deliver.

Where the sprinkler systems can be designed in two or more sections and the arrangement of buildings permits taking connections from different street mains, or from well separated points on the same main, it is better to provide two or more 4-inch connections, each supplying separate and independent sections of the system, where this can be done without unduly increasing the cost or decreasing the efficiency of the sprinkler system.

This reduces the chance of one break causing a serious waste of public water, or an interruption of service to more than one section at a time. Where pressure is high and mains large, 4-inch services will often supply ample water; where pressure is low or mains small, larger services are necessary to bring enough water to give efficient sprinkler protection.

Where in city risks the controlling valves required by Article 3 are favorably located so that they would be accessible and likely to be properly handled in case of fire, 6-inch connections could more freely be permitted.

3. All such service connections to have outside controlling valves in one of the following ways:

a. At the curb line with an indicator post.

b. At the building line with an indicator post set in a recess in the building wall.

c. In a valve pit near the middle of the street, or at the curb if a cover in the street is liable to be obstructed by snow or ice.

d. In bad cases, the connection may be looped back and the indicator post or valve pit set on the opposite curb across the street from the building protected; or the connection may, in some instances, be offset so as to come opposite an adjacent building rather than the one supplied.

e. Frequently the controlling valve can be placed opposite a stair tower or a division wall, where there is the least chance of falling walls making it inaccessible.

f. A hand wheel should be kept on each valve, and valves of the outside screw and yoke type should preferably be used.

Street mains should be so gated that in case of necessity not more than a block length, or a maximum of 500 feet of main will be shut off.

4. All valves on fire services to be plainly marked with the direction to turn to open, size of service and what it controls.

This marking can go on indicator posts where they are provided. Where the valves are in the ground plain signs should be put on adjacent building walls, giving also the distance in feet to the valve. It is probable that some uniform sign in wording and color can be developed for any one city which would be recognized wherever seen. It may further be possible to have a standard adopted for use in all places, thus giving the quickest recognition to such valves.

5. All manufacturing connections above 2-inch to be similarly provided with gates.

6. In cities having a number of buildings protected by sprinklers a small squad of intelligent men should be organized to handle the valves in case of fire under the direction of the chief of the fire department.

This squad could be formed either from the fire or water department, or possibly from both. With the growth of automatic sprinkler equipments it is necessary to have an efficient body of men who will understand the value of sprinklers and the best method of handling them to take charge of these matters at severe fires. The fullest use of private protection requires in cities that valves be cared for by men who especially understand the whole system and who will work in full conjunction with the public department.

It is to be regretted that there is a sentiment based upon more or less friction between the officials of the water works departments and what have been referred to here as "insurance interests", because the aim of both is to furnish the best public protection which it is within their means to provide; and this can only be accomplished by both interests getting together and going over these matters very carefully. The speaker will suggest that the American Water Works Association appoint a committee to act in conjunction with the committee now in existence of the National Fire Protection Association, to go over this question candidly and in detail, and to formulate a set of rules, which are very much needed at the present time.

Mr. J. M. Diven: That is exactly what we are leading up to, the appointment of a committee. While we have not discussed all these questions in their order, they have all been pretty thoroughly discussed; the speaker offers the following resolution: *Resolved:* that the incoming President, with the sanction of the Executive Committee, appoint a committee to draft rules and regulations for private fire services, with authority to confer with similar committees of other bodies and organizations.

The motion was promptly seconded by several parties in different parts of the hall.

Mr. George Houston: The speaker believes that the American Water Works Association is perfectly able to take care of its own business and does not understand why there is any use of our conferring with any organization outside of ourselves, or why we should hesitate to pass our own resolutions among ourselves.

Mr. J. M. Diven: In making the motion other water works associations, the New England Association particularly, were considered, not insurance organizations especially.

Mr. George Houston: The speaker would be glad to withdraw his objection and to have the New England Association included.

Mr. J. M. Diven: The motion was to confer with similar committees, and the maker of the motion believes that the association can safely leave it to the committee what associations or committees should be conferred with.

Mr. W. C. Hawley: The speaker hopes this motion will prevail. Those of us who are familiar with the discussions that have been had in the past remember that twelve or fifteen years ago the representatives of insurance companies were demanding that which was absolutely unreasonable and unfair. We come up against that still out on the firing line at our homes.

Now these gentlemen who have come in here today have apparently gotten around pretty nearly to our point of view, and we may hope if we can confer with them that ultimately their ideas will get out to their men on the firing line. Perhaps that may help to alter the unreasonable requirements that are demanded by their men outside at the present time. If a committee of this kind can be appointed to confer with these gentlemen we may hope for good results.

Mr. A. W. Cuddeback: It seems that the mere fact that this question has been so long before the water works associations for solution, and that we have not yet arrived at a definite conclusion of the necessities of the case, points to the desirability of all parties

at interest getting together. The speaker is purely a water works man, and has no particular sympathy with the insurance people; but has found in his dealings with them that there is a very decided change of sentiment from that of some years back; and believes that the time has come when we can all work together.

The question will never be settled by one side alone working independently of the other. The manufacturers are as vitally interested as any of us and should be considered in this conference; and if they have any organization which can be represented, why not include them in any conference committees that may be appointed. There is just as much stubbornness on the part of water works men as there is on the part of insurance men on this matter, and the time has come when we should get together on it. The speaker therefore moves to amend Mr. Diven's motion, to the effect that the committee to be appointed by this Association have power to confer with a committee from the fire insurance people and also a committee representing the manufacturing interests, if such committee is in existence.

The amendment was seconded.

Mr. J. M. Diven: The amendment is accepted if the seconder of the original motion will consent. There was no intention of limiting the committee, but to leave it to their judgment what other bodies to confer with.

The motion as amended was put and carried.

SPECIAL TOPICS

DISCUSSION

Mr. F. D. Manville: Has any member had experience in expanding fire hydrant hose nipples and cutting new threads that conform to the standard thread adopted by this and other interested associations. That is, expanding a nipple with finer threads or of smaller size so that the standard threads can be cut on it?

Mr. E. E. Davis: The speaker had a number of hydrants that needed expanding, and concluded that the best thing to do would be to take them out and put in new nozzles. The nozzles were 2-inch; the fire department asked for 2½-inch. The best that could be done was to make the nozzles 2½ inches; at the same time we bought a die and ran it over them to be sure that they were all right. The threads were made to conform to the requirements.

Mr. J. M. Diven: Would your hydrant barrel take in a larger nipple?

Mr. E. E. Davis: Oh, yes; where there was a 2-inch hydrant we took them down and put in larger, of course.

Mr. F. D. Manville: The Ohio Inspection Bureau at Columbus, Ohio, advertised the expander.

QUESTION BOX

Is a cast iron pipe when spongy acceptable if filled with cast iron cuttings and sal ammoniac? Has any member here had any experience in that direction?

Mr. J. M. Diven: Our specifications for cast iron pipe distinctly prohibit that, but it is remarkable what an under specification water pipe will stand. At Troy, New York, a pipe laid in 1833 burst recently. It was the old style cast horizontally and uncoated pipe, cast in 9 foot lengths. A section of this pipe, not where it broke, was found to be a shade over $\frac{1}{8}$ inch thick. The pressure when the pipe burst was 60 pounds on a recording gage about two blocks from the location of the break. For nearly the entire length of the pipe the thickness on one side was about an eighth of an inch, most of the metal being on the other side of the pipe, probably the top side in casting, the core having settled some. Near the break, and where the pipe was not much thicker than the thinnest section, there were two drive ferrules less than 5 inches apart, but the pipe did not give out near them. That a pipe in its thin section only about one quarter the standard should hold so long sets us to wondering if we are not buying too much iron when we purchase standard pipe.

President Hill: The remarks just made by Mr. Diven are worthy of comment; that is, whether we are not paying for too much iron. There is a tendency in all water works to increase the pressure on the pipe lines as time goes on. Towns are frequently built in valleys, near to the water courses, so that as they build up and develop they extend out on the hills and it is necessary to introduce fire pressure or to separate service districts, and the tendency is to use more pressure on the pipe than the original design called for. Under these circumstances, the margin of safety is most useful. It is undoubtedly true that in all engineering structures we should play safe, and the factor of safety as it is called is usually from 5 to 10. It is to be expected, therefore, that any engineering struc-

ture will stand somewhat more than it was actually designed for, but, on the other hand, experience has shown that it is not safe to eliminate the factor of safety, that theoretical computations with regard to the strength of materials have certain limitations, and that all materials show variations in strength for which some provision has to be made. You may, as pointed out, have an extremely thin pipe which will stand pressures you would not have expected it to stand, but, on the other hand, you have no doubt had the experience many times of pipes bursting under pressures much lower than they were designed to stand. You have, therefore, to strike a happy average in order to get safe results.

Mr. J. M. Diven: At Troy, New York, a consumer wanted high pressure at his place. His place was about 700 feet from the dividing valve between the high and low service. To accommodate him the high service was extended to his place. The pressure went up to 155 pounds, and at night to 165 pounds. The pipe is Class B, and stood the high pressure, no leaks occurring.

Mr. E. E. Davis: Probably the speaker's experience runs about as far back as that of any man in the Association, having been in the department forty-three years, and having had all sorts of experiences. Of some Class A pipe working under 90 pounds pressure one burst, and when it was cut out it was found to be chip-cracked. In another case a 10-inch pipe that was laid in 1830 was tapped. The bottom of the pipe was $\frac{3}{4}$-inch thick and the top was less than $\frac{1}{8}$-inch thick; yet that had been working under a pressure varying from 60 pounds to 100 pounds. We used to have lots of trouble when we were using the compression hydrant. Since we adopted the gate hydrant we do not have that trouble. We had two lines laid down that were tested by the factory; in each of these there was a large break; one of them was on a centrifugal pump line, the other on the bottom of the river. The reason for those breaks was never found out. The man who manipulated the butterfly valve was accused of being responsible for the break, at least he was made to believe he had done it. You can not get a water-ram from a centrifugal pump, that is a physical impossibility; but with a plunger pump it is different, because the action of the pump varies.

Mr. C. W. Wiles: With referenee to cast-iron pipe, the speaker had a somewhat similar experience, to that which has been related,

some three years ago. This was a 16-inch line. A crack occurred on the side of the pipe, and was some 6 or 8 inches long, going around one side right in the middle of 16-inch pipe. The ground showed no evidence of its ever having been moved. It was laid in heavy clay soil, and the pipe could not have moved. The pipe opened up vertically. That is one of those peculiar things that happen to pipe that we never can explain the cause of.

Mr. Wirt J. Wills: Cast iron pipe works "in a mysterious way its wonders to perform." Here is a little occasion where it worked in a very peculiar way. A 36-inch trunk line broke about 4 feet from the spigot end. It happened to break right by a creek, so that the excess flow of water could easily be taken care of, and it did not tear up the street much. When we went to get at it, by some hook or crook, nobody knows how, it cracked directly in line, right straight along the bottom, so that we only had to cut off about 18 inches. The speaker is telling you this to show you that there is some hope for cast iron pipe. Most of the time it is the other way. That saved us six or eight hours' work.

Mr. J. M. Diven: Speaking of saving time in cutting out pipe; the speaker broke out a 30-inch cracked pipe with dynamite. Three one-pound sticks of dynamite were used; broken up into $\frac{1}{4}$ to $\frac{1}{3}$ length pieces. These were "mud capped" along the pipe, that is secured in place with clay. All were fired together, using a battery. The pipe was thoroughly broken up, and several hours time saved. This was done on a built up street and no damage done. The only precaution taken was to ask the residents to open their windows. Some mud was scattered, but no iron.

Question: Is there an automatic hydraulic working check valve for closing either way when a break takes place on a large water main?

Mr. J. N. Chester: There are several of them.

Mr. J. M. Diven: Do they work automatically in either direction?

Mr. J. N. Chester: Yes, sir. They work just the same as a non-return valve that you put on a boiler. If a cap blows out, it closes

against the other boilers; or if a pipe bursts beyond the check valve between the boilers and the engine, it will close it. When the pressure lowers to a certain amount the other side of it, it will close.

If you will look in the catalogues of most of the steam specialty houses you will find such valves advertised. The speaker has recently received bids from two different concerns, on 20-inch valves which were purchased and installed and work all right.

The problem to be solved was a 20-inch rising main to a reservoir along a side hill suspected of contemplating a slide, which, if it occurred, would certainly sever the main and not only empty the reservoir, but do great damage to inhabitants and property below. We, therefore, wished to install some sort of a device near the reservoir that if the pressure was suddenly released below it would close against the backward discharge and still permit a flow through it in either direction under normal conditions. We had no trouble procuring prices on such a device, together with guarantees, which in the case of the one purchased we tried out.

Devices like the above are built so that they will close from a drop of pressure on either side and have been mainly developed by the requirements of large boiler plants, where the danger of shutdown from ruptures needs to be avoided in order to minimize losses from the shutdown of the entire plant.

QUESTION: What percentage of water pumped is unaccounted for after all meter readings, pump slippage, flat rates, fire protection and leaks are known, or carefully estimated?

MR. J. N. CHESTER: The speaker is not the man that asked that question, but it is the question that is worrying the Water Consumption Committee. In one water works in which the speaker is interested, we can account for not more than 40 per cent. Another plant accounts for 85 per cent. There are water works that produce results all the way between those two figures; but the complaint is that there are not enough authentic results or tabulated data on the subject that can be presented to rate-making bodies, who think we should account for 100 per cent. In another case a commission sent a man to a plant, where he found how much the pump counters showed delivered, and then divided the amount to be earned by the thousand gallons displacement, the result of which he reported to the commission, and they rendered a decision that the rate should

be 11 cents straight; if that decision had stood the plant would have been out about 50 per cent loss of revenue, because that plant was not accounting for over about 50 per cent of pump displacement. If we could get enough data tabulated to plot a curve, it would be of inestimable value in such cases.

The speaker would like to hear a pretty free discussion of this question; but he fears there are not many that can give definite figures, that is, who have taken the trouble to add up their meter readings at the end of the year, or have a master-meter, or figures showing delivery of the water through a pump, the slippage of which is absolutely known.

President Hill: The chair is interested to know about the case that you spoke of where 85 per cent was accounted for, as to whether it was obtained after a careful analysis; because that seems very high. Very few plants account for much over 75 or 80 per cent of the water actually delivered to the mains.

Mr. J. N. Chester: Mr. Huy reports that he found plants within a certain radius around Buffalo that accounted for 91 to 92 per cent last year, and that one division of the plant went down to 83 per cent, or something like that.

President Hill: Was that made from actual measurement, or from some assumed pump slippage?

Mr. J. N. Chester: They have master-meters and a record of all of the consumers' meters; but that is a very high result. Mr. Hawley of the Pennsylvania Water Company, the speaker believes, got above 85 per cent once, and then dropped below it. At Jefferson City, Missouri, under flat rates, allowing for the amount consumed by metered consumers, it went over 80 per cent. At Edgeworth, Pennsylvania, we have gas-engine driven triplex pumps and all consumers metered, and they are accounting for a little over 40 per cent and still we could not save enough in ten years to pay for a pitometer survey, if by so doing we could account for all, because our gas bill is small; but there are few consumers per mile. It supplies a suburban territory. Another thing, the pumps draw from driven wells, and when they start they sometimes run quite a little before they pick up the water, and the counter is counting just the

same in the meantime. There is doubtless a large percentage that goes in that way; but the rest of it must be air and leaks in the mains, or failure of the meters to record, or a great many other things. The speaker has found percentages varying from 40 to 92 per cent; but still has not enough of them to establish something really permanent and convincing.

Mr. Charles W. Sherman: These notes relate to the experience of the town of Belmont, Massachusetts, where the writer is one of the water commissioners. This town is a suburb of Boston, a residential community of 8000 people, with no manufacturing, but where there is a considerable use of water by market gardeners. The water supply is obtained from the Metropolitan Water Works, and is metered at the town line, where it is furnished, into the distribution pipes. The distribution system consists of 31½ miles of main pipes 2 inches to 12 inches in diameter, and 14¾ miles of service pipes, with 1430 services. It has been fully metered since 1898. The daily consumption for 1915 averaged 52 gallons per capita.

Not only are all the services, including municipal buildings, supplied with meters, but there are meters on watering troughs, etc., and the water department furnishes a man and a meter to measure the water used for sewer flushing. In fact, practically all the water used is metered, except that drawn from fire hydrants for extinguishing fires.

The proportion of the water supplied, which has been thus accounted for, has been as follows:

	per cent
1908	67.2
1909	65.6
1910	58.5
1911	61.0
1912	62.3
1913	64.2
1914	71.9
1915	82.5

No definite data are available to indicate where the unaccounted water goes. In 1910, following the decrease in the proportion for which we could account, it was thought that there must be a considerable number of leaks in the main pipes, and great pains were taken to find such leaks. These efforts did not meet with much success. Some leaks were found, but none of much consequence, and as shown

by the percentages, the gain in the next three years amounted to only about 5 per cent. It was then concluded that greater care in looking after house meters might show a further gain. Previously they had received good ordinary care; they were supposed to be read monthly, and it was believed that a meter could not be stopped or in bad condition for any considerable period without discovery. However, beginning with 1914 a systematic following up of all meters was undertaken, and no meter was allowed to stay in service more than a certain limited time, without removal, testing and cleaning. This policy resulted in a gain of 7 per cent in the water accounted for in the first year, and a further gain of 11 per cent in the following year. How much further gain can be accomplished in this way we do not know, but we are inclined to believe that not over 10 to 15 per cent of the water supplied is lost through main pipe leaks, and it may be possible to account for between 85 and 88 per cent of all the water supplied.

In this connection it may be interesting to note that in 1915, in the high service district of Belmont, a section including about two miles of 6-inch and 8-inch pipe, on a portion of which the pressure exceeds 160 pounds per square inch, and 47 services the percentage of the water supplied which was metered to consumers, was 94.

Mr. J. N. Chester: The trouble is to find plants that are thoroughly metered, that have master-meters, as the one mentioned by Mr. Sherman has. That is a contribution very valuable to our records.

The Springfield Company near Philadelphia is so metered, but the Water Consumption Committee has been unable to get the data from it.

Mr. C. W. Wiles: The speaker undertook to find out what water was getting away last fall. We have to take the pump records, and intend to put in a master-meter, to check them. The pump records, and then the meter readings for the year are taken. The sprinkling wagons are all metered; the city buildings are metered; about 72 per cent of the consumers are metered—all of the large ones. In the smaller services it is not considered that there is much loss as they are carefully and frequently inspected. There are only a few kitchen faucets or toilets that are not metered. In that way about 62 per cent was accounted for, but the speaker was so much surprised that

he appealed to Mr. Chester to know what the matter was. Of course, that loss of about 40 per cent was included in the fire protection. Our fires are not large, and there is very little water used for fires. It also could be accounted for by flushing hydrants. We have some dead ends, and also five or six water fountains, which have very small streams, but do not believe that on our main lines we have many leaks, as we have an excellent pipe system, and have never been able to detect very much of a leak on our pipe lines. Of course, the service lines do leak; but such leaks are taken care of within twenty-four hours, and we never allow water to run to waste. The allowance for fire service, flushing hydrants, horse troughs, fountains, and possible leaks, must be deducted from the 40 per cent unaccounted for water. Some engineers who have been consulted on the subject, thought that ought to take care of pretty nearly half of it; so that would leave us in the neighborhood of 20 per cent, or a little over, unaccounted for.

Mr. Wirt J. Wills: This is a subject that most water works people have given a great deal of thought to. The speaker has been working on it for a number of years, with some results. Last year, 1915, he went at it a little more particularly than ever before, and accounted for about 40 per cent of the water. Out of the other 60 per cent comes all the water that is furnished the city for fires and the street sprinkling. Memphis has 150 miles of streets to sprinkle all the time. Then there is water for sanitary purposes, flush-tanks, and all that sort of thing. The city is about 27 per cent metered; the balance on a flat rate. The pumping record shows that, ten years ago the daily average was 15,000,000 or 16,000,000 gallons. In 1915, with a population of at least 135,000 people, the average was less than 12,000,000 gallons a day. The use of a pitometer combined with very vigilant inspection in those five years has saved us a great deal. That inspection business has been carried to such an extent that sometimes they say the speaker is arbitrary; for instance, if one of our men who live down the street walks up from his place and fails to see a leak, and the speaker comes along afterward and finds that leak, he gets after that man and asks him why he did not report the leak. If he repeats that performance three times he loses his job. It may seem hard, but it saves a lot of water.

We found one 4-inch line running into a creek; the water had been running away there twenty years, and nobody knew it.

Mr. Henry P. Bohmann: With the exception of the automatic sprinkler systems and the public drinking troughs and bubblers, all water in Milwaukee is metered, the pumpage being based on the displacement of the pump plungers. After allowing 5 per cent for pump slippage and 3 per cent for under registration of meters, there remains "unaccounted for" 12 per cent. The metered consumption is about 72 per cent, unmetered about 8 per cent. A very close estimate is made of the unmetered drinking troughs, by taking an average of 10 drinking troughs in different sections of the city, estimating the consumption by stop watch and pail measurement. The amount used for fire protection is obtained from the Fire Department. We are informed of the time each engine is operated at a fire, the rated capacity of each fire engine being known, and figure the pumpage 50 per cent of their rated capacity. The amount of water that is used for settling sewer trenches is estimated, and even the amount of water that is used for filling new water mains that are laid, is taken into consideration. Where mains are flushed, the time that the hydrant is open is kept track of, and the pressure at that particular point, so that we can figure out how much water is used for that purpose. After all our figures are in we find only 12 per cent unaccounted for. We have not been able to reduce this figure in the last three years. We can send our report in to any one who is interested in this subject, showing the amount of water used for domestic use, for industrial and municipal use; the exact quantities for each. The speaker has often wished that some of the other cities would do the same thing, so that we could make comparisons. Cleveland is about the only city that keeps a record of the amount that is actually pumped and accounted for.

We are installing Venturi meters at the pumping station so that in another year the question of slippage will not have to be estimated. We have put that at 5 per cent for the past three years.

President Hill: Have you made any comparison of your results with theoretical losses that were obtained from meters in service, say based on the tests that were made in Columbus, which were very fully published in the *Engineering Record?* Tests were made of new pipe carefully caulked and under the best supervision. There is a residual loss which can not be prevented. How close to that theoretical loss have you ever worked that out? How close to the theoretical have you come?

Mr. H. P. Bohmann: We have not worked it out that way. The statement has been frequently made that no water works is accounting for more than 75 per cent even where they buy their water by meter measurement and sell it by meter measurement; but we find that leaks in our distribution system are not of great importance. We have had mains in service thirty or forty years that have never developed a leak.

Mr. Frank C. Kimball: Speaking in a general way of a water works in New Jersey, where the water is bought by meter measurement, there are three supplies in the town, high, intermediate and low, each one of which has its own meter. There are about 39 miles of pipe in the place, and something over 2100 services. All the water is metered except about 15 services, and of course the fire uses, together with such water as is used for flushing mains. The quantity used for fire purposes is estimated by the time the hydrants are opened, the pressure, length of hose, etc. The amount used for flushing sewers is also periodically measured. When the mains are flushed a pressure gauge is put on the hydrant, and a record is kept of the time it is open, so that the water is practically measured.

The records for the first quarter of this year, after making the usual estimate for the 15 unmetered services, show within a fraction of 90 per cent accounted for, on the high service; on the low service practically 93 per cent and on the intermediate service, it was just a little under 81 per cent. The percentage accounted for on the system as a whole was 87.7 per cent. That is a case where the water is all measured that comes into the system and as near as can be told by metering substantially all services and estimating by the time, pressure, size of nozzles, etc., water used for fire purposes, as it goes out. This has been brought to that state by constant watching. Two years ago 75 to 80 per cent was accounted for. The pipe system has been followed up by a systematic investigation until various leaks have been found and repaired, and the record for the last year, 1915, was somewhere around 87 to 88 per cent accounted for. The three master-meters on the inlet pipes are read every week.

There is a large factory installation in that town supplied through some fourteen meters, which are read every week. Their use is more or less erratic. The sum of these fourteen meters is subtracted from the two master-meters supplying the pipes upon which they are located, and if the remaining uses of water do not, week by

week, show a fairly straight line of consumption investigation is made to find out what the trouble is. A year ago last January the consumption apparently increased very rapidly. The usual superficial examinations discovered nothing; and after a week or more of rather strenuous work, a gentleman living in a certain part of the town wanted to know what made the noise that he heard in his house. Just such noises as that were being searched for. Nothing was found in his place, but nearby there was quite a racket at a sewer manhole, and on going down into it there was found a stream of water running into the sewer about 16 feet below the street, very close to the bottom of the sewer. A main was found close by that, in settlement, had broken off vertically. This was repaired and the percentage of consumption accounted for jumped up to its usual level. These things are followed up through the use of the master-meters practically once a week; and the accounted for consumption is kept up to a point around 90 per cent, but it requires eternal vigilance to do it. This is about as near perfection as it can be, and formerly 75 or 80 per cent was satisfactory.

Mr. C. W. Wiles: Accounting for water used for fire purposes by measuring the speed of the engines was novel and interesting to the speaker. In Delaware, Ohio, we have a high pressure and do not use any engines; and have been trying to evolve some scheme to find out how much water we use at a fire. We have a pump that is running continuously; when we have a fire we start another pump. We run the fire pump at something over the rate of speed that the other pump runs for domestic use. We have instructed the engineers at the station to make an accurate record of the minutes that the fire pump is running, and are trying to see if we can not get from that some kind of data of the amount of water that is being used at fires. It is evident that the domestic use will be about the same; and the other extra pump will show the fire use.

Mr. A. P. Folwell: In New York City every foreman hands in a report of the number of lines of hose laid; the time that the water was flowing through each line, and the size of the nozzle used. From these reports the amount of water used by the Fire Department can be calculated quite accurately.

Mr. Henry P. Bohmann: In Milwaukee the practice is for the fire department to make a report of the hours and minutes that

each fire engine is operated at either a fire plug or fire cistern. For the information of the members of this association it may be stated that the amount of lake water used during 1915 was 13,000,000 gallons out of a total pumpage of 17,000,000 gallons. We also have four fire boats that pump river water into an independent pipe line. The amount of river water pumped by these four fire boats during 1915, was 12,000,000 gallons, making a total amount of water pumped for fire extinguishing purposes of 25,000,000 gallons, of which 13,000,000 gallons was domestic water from the distribution system of the water department.

Mr. J. N. Chester: Will the gentlemen who have taken part in this discussion, when they revise their remarks, give us some tangible figures? The discussion by Mr. Sherman gives percentages throughout a number of years. This would be accepted as evidence, if given properly. Let all sent in be such that it may be tabulated in such a way that from it we can make up some aggregate figures.

President Hill: The New York high-pressure fire system is a closed system; and they have been keeping a record at the pumping station of the amount of water that they have to pump in order to keep the lines full.

Mr. J. N. Chester: Baltimore has such a system. They have a direct acting pump which keeps the mains full.

President Hill: They have centrifugal pumps in New York. It occurred to the speaker that on a closed system like the New York high pressure system one could obtain an excellent index of the residual loss which might be reasonably expected through leakage in mains and an idea of the minimum loss to which one could hope to attain. Could we not get someone to contribute to this phase of the question?

Mr. Edward S. Cole: In an excellent paper by Mr. E. G. Bradbury of Columbus, Ohio, published in the *New England Water Works Journal*, vol. xxviii, page 315, the author gives the results of leakage tests on new lines of pipe before connections were made, indicating a loss per mile per inch of diameter of 100 to 200 gallons daily. This, of course, allows nothing for leakage from service pipes.

The late Mr. Emil Kuichling estimated an average loss of 2500 to 3000 gallons daily per mile of main, based upon one drop per second per joint in the main, five drops per second for each hydrant or gate valve, and three drops per second for each house service pipe. The Kuichling estimate of 3000 gallons per day per mile is not too high in many cases. In an old system especially with inferior service pipes we find all rules will fail.

In regard to water accounted for; a well managed water works, practically 100 per cent metered should account for about 85 per cent of its supply. Total supply should always be determined accurately by master meters, and on the other hand, slip of service meters and unmetered use should be determined as closely as possible, but should not be over estimated in the effort to cover up a large discrepancy.

A Member: The speaker has been deeply interested in this discussion and would like to give you the benefit of some of his experience. It is doubtful if any of you superintendents here will ever be able to come very close to the percentage of water that you are accounting for. Perhaps our municipality is a little different from others, because of the fact that we are under municipal ownership. The State Department of Agriculture, on account of an epidemic of glanders, ordered the discontinuance of the use of drinking fountains for horses. We found that that very materially assisted us in accounting for some water; that there was a great amount of water going to waste through these drinking fountains. The present mayor of our village said that he wanted those drinking fountains removed because they were an eyesore. In order to prevent them from being an eyesore they were converted into beautiful flower gardens; so that now they are "a thing of beauty and joy forever." Self-closing faucets have been placed on the outside of each trough, so that teamsters can water their horses by drawing water from those faucets.

We furnish water to the fire department. We have large streams of water going into the different lakes in the parks. We furnish water to all the municipal buildings and for street sprinkling; yet we cannot account for over 50 per cent of the amount of water that we are supposed to be pumping. The only way we can account for what we are pumping is by the strokes of our engine, which is a rather inaccurate method and which requires an allowance for slippage.

Mr. Frank C. Kimball: One reason for our getting the close registration reported is that within the last three years practically every domestic meter on the system, something over 2000 altogether, has been taken out, cleaned, recalibrated, and reset, or else new ones supplied in their place, It is quite evident that a large part of the unaccounted for water is due to the small domestic meters not registering properly. We all know that, as much as the consumer holds the opinion to the contrary, the individual or domestic meters register, as a rule, against the water department.

Mr. J. M. Diven: That brings up a question which is apropos here as to the frequency with which meters should be tested or replaced. Some base the reply to this question on the amount of water which has passed through them; others on the time that they have been in place. Probably the character of the water has something to do with it. The question is, how frequently should meters be taken out or tested?

Mr. C. W. Wiles: All meters are tested to register a little below 100 per cent when they come from the factory; new meters do not register quite up to the amount of water passing through them; the manufacturers expect that they will run under. Of course, the longer they run the greater percentage of loss there is. In a plant with 5000 meters, it is a pretty safe estimate to figure the percentage of actual water passing through as under registered at 4 or 5 per cent. This arises from different causes, and also from the original cause that no meter is expected, when it leaves the manufacturer's hands, to measure quite up to 100 per cent. That explains unaccounted for water to some extent. It is not fair to figure the percentage on the amount of water that passes through the meter as shown on your books as being the exact amount of water which actually does pass.

Mr. George Houston: The amount of water accounted for through meters during the last year in the Kalamazoo plant was 415,000,000 gallons out of a total of 725,000,000 gallons pumped. That simply includes all metered water. Our city is 100 per cent metered, excepting street washing, sewers, watering troughs and drinking fountains which may be included in the water accounted for and which will add about 15 per cent to the total before mentioned. That makes the amount of water accounted for about 72 per cent.

Mr. C. F. Schulz: Cleveland, Ohio, accounts for about 94 per cent. Of course, our method of figuring has been a little different. The discharge mains of all our pumps are metered with Venturi meters, which show on an average not over 1 per cent of pump slippage. However, in accounting for the water pumped we deduct 3 per cent from the pump plungers displacement to determine the water delivered to consumers, and call that 100 per cent. Besides Cleveland we are supplying about thirteen villages with water; we have about 950 miles of water mains with over 95,000 service connections, exclusive of village mains and services. About 99 per cent of all services are metered. The metered water accounts for 88 per cent of the water which we consider has been delivered by the pumps, after deducting 3 per cent for slip of pumps and calling that quantity, i.e., the quantity delivered by the pumps, 100 per cent. We keep a record of all the water used for putting out fires, which is not much over 40,000,000[1] gallons for the entire year, or half a day's consumption. We also keep an accurate record of the water used for settling trenches, flushing sewers and for flushing mains and for various other purposes; for instance, we have one gang that flushes dead end water mains continually throughout the year. In addition to that we have a few connections that are not metered; we also furnish unmetered water to public utility corporations for construction purposes. We assume that the quantity of unmetered water furnished for these various purposes amounts to less than 3 per cent of the total pumped. All these together amount to about 94 per cent of the total pumpage. We have tried to be honest with ourselves. We have no means of determining losses caused by overflowing of reservoir. Water in the reservoir sometimes overflows 3 or 4 inches. No doubt a great deal of unaccounted for water is lost in that way.

Mr. W. F. Wilcox: Do you supply any public water, unmetered, to any of the thirteen villages supplied?

Mr. C. F. Schulz: We have meters at the city boundary line. All the water supplied to villages goes through meters. We further require that all villages shall meter every service connection for their own protection to enable them to know just how much water they account for, and they do account for a large per cent of the quantity delivered to them.

[1] 40,770,000 in 1913; 51,154,000 in 1914; 74,566,000 in 1915.

President Hill: In view of this discussion, how are you going to justify yourself before courts for that unaccounted for 40 per cent, Mr. Chester?

Mr. J. N. Chester: Answering Mr. Hill, we must face the facts as we find them. Mr. Schulz said that the Venturi meters showed a pump slip of 1 per cent, and then said he took off 3 per cent. He further says that all water is metered and that the service meters register 88 per cent of the water passing the master meters. Now, that would make it 86 per cent, would it not?

Mr. C. F. Schulz: We account for 88 per cent. We allow 3 per cent for slip of meters. We deduct 3 per cent from the plunger displacement to give us the amount of water furnished to the city.

Mr. J. N. Chester: What do the master meters show?

Mr. C. F. Schulz: According to the Venturi meters which measure all the water which leaves the pumping station the pump slippage averages not much more than 1 per cent. We have considered the Venturi meter not as accurate as the plunger pump when it comes to measuring water, and have assumed a slippage of 3 per cent in the pumps; or, in other words that 97 per cent of the water that the plunger displacement indicated was actually delivered into the distribution system.

Mr. J. N. Chester: Commissioner Pennypacker, of Pennsylvania, after listening recently to a line of such testimony as we have had here today, interrupted the witness by saying it reminded him of a story of how the Dutch in early Colonial days determined the weight of goods purchased from the Indians. He said they would fill up one side of the scales with the article to be weighed, and then put enough stones on the other side of the scales to balance, and then guess at the weight of the stones.

Mr. W. F. Wilcox: When the speaker was discussing Mr. Chester's own paper he objected to "rule-of-thumb" methods. But our constant examinations in checking up different departments have shown us that a Venturi meter will vary 1 per cent as a minimum. If you get a Venturi meter of large size within 1 per cent of accuracy, you are unusually accurate. Now we find with our pumps, which are about of the same character, generally speaking, as those at Cleveland, that about 3.6 per cent is good average operating condi-

tions. Probably Mr. Schulz is an operating engineer and has used his experience when he got that 3 per cent; therefore Mr. Chester should object to a "rule-of-thumb" method in arriving at that 3 per cent. Mr. Schulz takes the reading of every one of the service meters and they are added up exactly like a cash balance and are balanced against the Venturi meters. Mr. Chester must get back on the platform that he was on yesterday, and use scientific determinations, and not try to question Mr. Schulz by "rule-of-thumb".

Mr. J. N. Chester: The "rule-of-thumb" method is just exactly the objection. Mr. Schulz does not say whether he has added or subtracted 3 per cent.

Mr. W. F. Wilcox: You are trying to figure in both interest and discount. That is begging the question. Mr. Schulz has accounted for 85 per cent, and 3 per cent slip. The other 12 per cent is accounted for as loss. They have arrived at it by scientific research; they have taken the readings of each one of the little meters and added them up, as you would your nickels and dimes, and they have struck a cash balance; and you cannot come here with any "rule-of-thumb" and question that statement.

Mr. C. F. Schulz: The speaker's statement was perhaps confusing, because we deducted the pump slippage and then called the balance 100 per cent. Mr. Wilcox has stated very correctly that if we do not deduct for slip then we account for 85 per cent of plunger displacement.

Mr. J. N. Chester: You know absolutely that 85 per cent is right, for you have that. Now, you started with 94 per cent; and your method of arriving at the difference between 85 and 94 is a sort of "rule-of-thumb," is it not?

Mr. C. F. Schulz: Before we determined the amount of water used for putting out fires, for flushing sewers, and for filling trenches, we put meters on the fire hydrants, so as to get the rate of flow per hour. Then an accurate record was made of the time that each hydrant was used for any purpose. Of course, there will be some variation; but as stated before, we don't make any secret of how we arrive at those results.

The following table shows the percentage of water used for various purposes and the percentage unaccounted for during the years 1913, 1914 and 1915.

	1913	1914	1915
Nominal pumpage during the year	27,099,632,872	29,803,485,871	28,557,394,916
Slippage through pumps estimated @ 3 per cent	812,988,986	894,104,576	856,721,847
Total consumption to be accounted for, gallons	26,286,643,886	28,909,381,295	27,700,673,069
Total consumption to be accounted for, per cent	100	100	100
Metered and sold	82.98	78.57	82.03%
Metered but free	5.72	6.32	6.74
Total registered by meters	88.70	84.89	88.77
Slip of meters, estimated @ 3 per cent	2.66	2.55	2.66
Total water passing through meters	91.36	87.44	91.43
Estimated use of water by those paying on assessment basis*	0.045	0.01	0.003
Hydrant rentals*	0.12	0.11	0.144
Building purposes*	0.17	0.21	0.369
Sprinkling streets*	0.107	0.03	0.024
Estimated consumption for miscellaneous purposes not covered by hydrant rentals, building permits, etc.*	0.36	0.33	0.180
Unmetered free water for testing meters, building sewers, paving streets, puddling trenches, flushing water mains, flushing sewers, watering troughs, parks and fountains, fire extinguishment, etc	2.45	1.94	2.07
	94.61	90.07	94.17
Leakage from pipe system†	1.10	1.40	1.20
Total accounted for	95.71	91.47	95.37
Unaccounted for	4.29	8.53	4.63

* Estimated consumption for the purposes mentioned was determined by calculating the quantity of water that the money received on the assessment basis would pay for at the uniform metered water rate of 5¼ cents per thousand gallons. The actual quantity used for these purposes and the quantity wasted no doubt greatly exceed this estimate.

† Based on reports of leaks discovered by the waste detections department. No data as to duration of leaks. Data not reliable.

Mr. Nicholas S. Hill, Jr.: It is very gratifying to see so many water works men who are earnestly desirous of determining the actual distribution of the water which they pump, and the example of those gentlemen who have spoken today is one that should be emulated by all. On the other hand, before the preceding discussion goes on final record, there should be some modifying statement or the greatest injustice will be done to many water companies.

There are few plants which, from the speaker's experience, can show anything like the results which have been indicated here today by two or three of the gentlemen who have spoken. Now, what would be the outcome if we let these results go on the record as a standard? A great many water works will be done a gross injustice in establishing a rate scale. There may be some here who would not seriously object to that, but all fair minded men will realize that even a water company is entitled to its just dues. An injustice is done even to municipal plants by expecting too high a standard, so that this discussion may act as a boomerang on the superintendent of a municipal plant who will be called to task when he cannot account for as high a percentage of water as has been indicated by some of the speakers. A plant which is accounting for 80 per cent of the water pumped is a most efficient plant. Statistics would probably show that the vast majority of plants in operation today are not accounting for 70 per cent of the water pumped, some may fall below 60 per cent.

It may be well for the sake of accumulating data of this kind to summarize some of the things which must be taken into consideration if those who are present today go home and endeavor to get some data together relative to their plants. In order that these data may be useful for practical purposes, certain things must be taken into consideration. First, the speaker suggests the advisability of our Committee on Water Consumption preparing a blank, if they have not already done so, and that they send it to all the superintendents who are represented in the Association, outlining those elements which should be taken into consideration in order to obtain accurate and definite results. For instance, before a determination of the water consumed may be made, actual determinations of the pump slippage must be made. You cannot guess it. Pumps in one of the large pumping stations of the City of New York, which were supposed to be in good shape, showed 63.5 per cent slip. If that condition can exist with a high class pump in a large station,

will it not also be found in smaller water works? The high slippage mentioned was not due to plunger slippage, but to defective valves. The only way to determine pump slippage accurately is by volumetric measurement through the agency of a reservoir of known dimensions, by using a pitometer, Venturi, or some other equally accurate way. It is absolutely useless to make reports on systems that are partially metered and upon which estimates have to be made of the water consumed. Such estimates are nothing more than wild guesses. It is necessary that at least 80 per cent of the taps be metered in order that any estimate of the water accounted for may be reasonably accurate. On any metered system you must have records by which the total registration of meters for household, manufacturing and other purposes may be easily and quickly tabulated, so that your results are accurate in the end. Meters should be placed on all public buildings, sewer flushing connections, and other taps where water is supplied free. Otherwise, these losses will distort the result. It is also advisable to keep some record of the average acccuracy of meters removed from service after a reasonable period of time, so that the slippage of the individual meter may be determined. After all these elements have been taken into account, you still have to provide for the water used for fire purposes, which cannot be metered.

The speaker wants particularly to dwell on the water used for sewer flushing. He does not carry figures in his head, but does know that in several instances where he has had the opportunity to make actual measurements of water consumed by flush tanks, he has found that it is about 100 per cent more than it is usually estimated to be. You cannot make any rational estimate of the water accounted for unless you have an accurate record of the water which goes for sewer flushing. Now, after all of the precautions above indicated have been taken, it seems that the data should be set up in standard form, and there should be copious notes with regard to the characteristics of the system. It is useless to expect a system with a low consumption per mile of main to show as low a percentage of leakage as a system which has a large consumption per mile of main. This is one of the characteristics which make a great deal of difference in the results which may be expected.

Then there is the question of reservoirs. A great many plants have reservoirs which are unlined. It is necessary to make some experiments on such reservoirs to determine what the average losses

from seepage amount to. These losses must be taken into consideration before the losses from the distribution system can be accurately determined.

Mr. W. F. Wilcox: At the Cincinnati meeting the speaker discussed this same question, and made this point then, and has looked into the question since, and sees no reason to change his opinion; that a water works which could account for only 65 per cent of the water was poor management; that 70 per cent was fair management; that 75 per cent was good management; that 80 per cent was excellent management; that 85 per cent was so very excellent that it needed to be questioned. Now, to recite some cases as for instance Cleveland, where Professor Bemis had stated that he accounted for 85 per cent; and according to information from men who have studied this question for years, 85 per cent seemed so uncommonly large that it called for investigation, not questioning the personal veracity of men of such high standing as Schulz and Bemis, but it left the rest of the water works people far in the shade.

Now any of the large meters will measure water within 1 per cent. A meter measuring an output say up to 1,000,000 gallons per day will cost $500 to install. That amount will hold up to a 25,000,000 gallon capacity meter, which will cost about $150 per 1,000,000 gallons capacity. There is no plant anywhere, no matter how poor and miserable and little it be, that can not afford to buy a $500 meter, because it will save them $500 worth of coal in two years, at the minimum. Mr. Schulz has stated that he supplies thirteen villages and that those villages take care of their own minor losses. That helped out the city showing, how many per cent it would be hard to say.

Another thing, a leak in a large town will seem infinitesimal, in a big plant like Cleveland for instance, whereas it might have considerable effect in a town pumping 500,000 or 1,000,000 gallons per day. When you compare a small plant to a big plant, leakages in mains and valves are absorbed very rapidly in the latter, but materially affect the small plant. You will remember the speaker outlined to you yesterday, in giving you a few little "rules-of-thumb", that the cost of operating a boiler plant, outside of the fuel, ran from $3 per b.h.p. down to 50 cents or maybe to 25 cents, depending on the size of the plant; and leakage percentages vary in the same general ratio. That may not be mathematically correct, but speaking

generally, a small plant can never hope to get as large a percentage of accounted for water as the big plants do. The small plants have been entirely too careless in not metering their output. It is the speaker's belief that any man that will buy a good meter of any of the several standard makes will save the cost of that meter, at the maximum, in two years. On a test it was shown that one valve on a 12,000,000 gallon pump made a leakage of 5 per cent; and there were 1564 valves in two pumps.

Mr. Frank C. Kimball: What our President says with regard to allowing this Association to go on record as saying that these large percentages of water accounted for can not be obtained in all cases is pertinent; because they cannot as a rule. In saying that the Summit works were accounting for practically 90 per cent it was particularly stated that weekly comparisons were made to be sure that the normal consumption was not exceeded during any given period. Six other municipalities in New Jersey are supplied with water by this company, and are supplied from two pumping stations, where the usual method of measuring the output are employed, namely, by the plunger displacement. There is an allowance of 5 per cent for slip in pumps. Of those six municipalities four are entirely metered, the other two are to an extent that makes the entire six average about 85 or 90 per cent metered; and after allowing 5 per cent slip of pumps a trifle under 80 per cent of the water was accounted for. That is the other side of the question. One reason for being a little more particular in the first instance mentioned is that the price per million gallons for the water purchased through master-meters is high. The difference there is apparent in dollars. When pumping the water the cost is not quite so apt to be noticed. It is not at all certain judging from the character and performance of the pumping plants, that the slippage does not exceed 5 per cent. With some thirty years' experience in operating water works plants, most of them pumping systems, the speaker believes that with all the care that can economically be used the average accounted for water should not be considered as over 80 per cent, and that it is under exceptionally favorable conditions, or under something more than usual good management, when it is maintained higher than that.

Mr. James B. Wilson: What precaution can be taken to care for mains laid through salt marshes or creeks where chemical action has

the same effect upon the main as electrolysis? The speaker has removed over 3000 feet of main, or abandoned it, in the past two years on account of such action.

Mr. Daniel D. Jackson: We have had considerable experience with regard to electrolysis affecting water pipe and the chemical action of acid clay on water pipe, in the Department of Water Supply of New York City. In analyzing those pipes which have been acted on by electrolysis from currents escaping from street railway lines, and those pipes which have been acted on undoubtedly by the chemical action of clays, we could find no differences at all in the appearance of the pipe itself. They were both very soft and could be readily cut with a knife, and the material left over was nearly all carbon, the carbon in the pipe being left over, and the iron being dissolved. Therefore, there is no means of determining what caused it from the chemical analysis alone, but only from examination of the conditions in that locality. And in those places where the conditions evidently show that it was the action of the soil, and not stray currents, the remedy is to have the pipe filled around with sand, so that the clay does not come in direct contact with the pipe. In this way all trouble from this source is largely if not entirely eliminated.

Mr. J. N. Chester: If Mr. Wilson will go down to Atlantic City and talk to the officials there, and look at their pipe graveyard, he will get further information. They have laid pipe there across salt marshes. Without wishing to discount Doctor Jackson's information at all, there are some startling things that can be seen there of what happens to cast iron pipe. They tried both wooden and steel pipe, and have recently resorted to cast iron pipe laid on concrete piers supporting it above ground and tide. Their experience is worthy of note and study.

Mr. Daniel D. Jackson: There is no question that the action is greatest in salt marshes. Where pipe has to go through practically salt water, sand itself is not sufficient. In such cases the pipe must be coated with tar or asphalt, and covered with concrete.

DISCUSSION

EARTHING ELECTRICAL SYSTEMS TO WATER PIPES[1]

Mr. S. W. Stratton:[2] The Bureau of Standards has had called to its attention the discussion in the March, 1916, issue of the Journal of your Association, on the paper by Mr. McCollum and Mr. Peters of this bureau entitled "Earthing Electrical Systems to Water Pipes". Some have thought that this discussion, partly because of its incompleteness, might give rise to some unfortunate and unwarranted apprehensions on the part of owners of water meters and might also possibly leave some misapprehension of the bureau's position as to the desirability of grounding telephone protectors to water pipes.

In order that the position of the bureau may be correctly stated, with regard to such ground connections, and in order to correct if possible any misapprehensions which may have arisen on this point, the bureau would be glad to have this present statement given publicity in your Journal.

Referring to copy of the National Electrical Safety Code with which the paper on "Earthing" was largely concerned, under rule 393 (a) (2) may be noted the following rule covering the ground connection of arresters and signal systems: "The ground connection shall be made to a cold-water pipe connected to the street mains and any service, where this is available." Neither experience nor theoretical considerations show any appreciable chance of damage to the water piping system because of such connections. The thoughtful consideration of the above mentioned discussion should indicate that the possibility of the heating of meters mentioned in that discussion as a possible disadvantage of permitting the grounding of arresters on water service pipes, is an exceedingly remote one, especially because of the small possible current flow to earth through

[1] A paper read at a meeting of the Central States Section of the American Water Works Association, and printed in the March, 1916, Journal, Vol. 3, No. 1, at pages 201–219. Answering discussion by Mr. Joe C. Beardsley, page 222.

[2] Director Bureau of Standards, Department of Commerce.

telephone arrester ground wires. In case of accidental contact between a telephone wire and a railway trolley or other high voltage wire, the current which could pass through the arrester is limited by fuses to about 7 amperes and the possibility of this causing any appreciable heating in even the smallest service pipes and their connections is entirely negligible.

To show how small the possibility of trouble is, it may be stated that the bureau also strongly recommends the grounding of low voltage alternating current light and power circuits entering buildings to the water service pipe.

The fuses limiting current in ground wires in this case may be as large as 50 or 100 amperes or in certain cases even greater, but even here 100 amperes in a single service pipe would rarely be encountered because multiple grounds are recommended and they would correspondingly reduce the current through any single ground, the total being limited by the fuses as hereinbefore stated. A cross between a high voltage circuit and a low voltage circuit is, of course, very infrequent, but in the infrequent case where the current does flow from such cause, it should be considered what the amount of heating might be in order to demonstrate the improbability of even 100 amperes injuring the smallest service pipe, for instance a $\frac{3}{4}$-inch wrought iron service.

The resistance of a $\frac{3}{4}$-inch wrought iron pipe weighing 1.11 pounds per foot of length is approximately 0.0002 ohm per foot. With 100 amperes flowing the rate of liberation of heat per foot of pipe would be $(100)^2 \times 0.0002 = 2$ watts, or 1720 gram calories per hour. The volume of water per foot of pipe is about 98 cc. Enough heat would be liberated in one hour, therefore, to raise the temperature of the water $1720/98 = 18°C$. To raise the temperature from 20°C. (68° F.) to 60°C. (140° F.), the temperature said to be necessary to injure the hard rubber parts of water meters, would require a current flow of 100 amperes for a little more than two hours. This however, makes no allowance for radiation of heat nor for circulation of water. If these were taken into account, the current required to raise the temperature of the water to 60°C. (140° F.) and maintain it would be a great deal more than 100 amperes. Only in extreme cases, therefore, is there any possibility of injury to water meters from heating of water in service pipes through grounding secondaries to them.

Either with low voltage secondary circuits or with telephone circuits, the duty devolves upon both the water utility and the wire-owning utility of protecting persons and property, and the existence of either by itself in a building is less dangerous than where both are present. Where both are present the prevention of a dangerous voltage between them is essential and no so-called ground connection which can possibly be made on a telephone or other low voltage circuit in any other manner can be compared in effectiveness to that made to the water piping. It is the recommendation of the bureau that grounding of such circuits be made to water connections in all cases where these are available, and either outside the meter or with bond connection around the meter so as to maintain the integrity of the connection in case of work on the meter or its removal. Careful investigation has failed to show any bad experience from such connections warranting either utility in failing to permit the instalment of this desirable protective measure.

THE SECTIONS

CENTRAL STATES

A meeting was held by Central States Section of the American Water Works Association in the Hollenden Hotel, Cleveland, Ohio, October 10 and 11, 1916.

The morning session of the first day was devoted to registration of members and a short business session. Welfare Director Lamar T. Beman, of the city of Cleveland, opened the afternoon session with an address of welcome. Jerry O'Shaughnessy, Columbus, Ohio, chairman of The Central States Section responded.

The paper by John M. Diven of Troy, New York, secretary of The American Water Works Association, on the "Object of Water Works Associations" created a splendid impression. "The object of the association and the convention is to bring water works men together so they may benefit by one another's mistakes," Mr. Diven said. "Our work is an important work, the prosperity of the communities we serve depends on our efforts more than on any other single thing. Not only the prosperity of the community but often the health, or even the lives of the residents are in our hands. So our responsibilities are great, and we should not hesitate to prepare ourselves in every possible way to do our full duty and safeguard the interests of those we serve. Can we do this in any better way than by joining the water works associations and keeping well informed as to water works matters."

Through the courtesy of Mr. J. C. Beardsley of the Thompson Meter Company, A. I. Fischer of Glauber Brass Company, Joseph Kiewell of Farnan Brass Works, all of Cleveland, Ohio, and Cleveland Water Works officials, the visiting delegates were taken on a tour of inspection to the West Side Pumping Station.

The second day's session appeared on the program as "Superintendents' Day" and was given over to the discussion of practical water works subjects.

Mr. J. M. Jones, supterintendent Water Company, Circleville, Ohio, led in the discussion of the following topics: "Materials and Methods in Making Service Connections."

The question as to whether all water taps should be metered and a minimum rate charged was ably discussed by Mr. J. C. Beardsley. Mr. Beardsley also discussed the question as to whether water meters increased the cost of water to the consumer, and the best method of testing water meters.

Mr. Jerry O'Shaughnessy, superintendent Water Works, Columbus, Ohio, talked briefly on the subject concerning the advisability of maintaining a repair department or sending defective meters to the factory.

Mr. C. W. Collins, Mannistee, Mich., led in the discussion of "The Material and Proper Method of Packing Stuffing Boxes on Hydrants and Gate Valves". The round table discussion of the above mentioned subjects proved very interesting and beneficial to the superintendents present.

The following officers were elected for the ensuing year:

Chairman, Elroy Tobias, Hastings, Mich.

Vice-Chairman, S. F. Messer, Kent, Ohio.

Treasurer, A. W. Inman, Massillon, Ohio.

Secretary, R. P. Bricker, Shelby, Ohio.

Director, T. R. Cook, Toledo, Ohio.

4-STATES

A meeting of this section was held in Wilmington, Del., November 15, but up to time of going to press, minutes had not been received.

ILLINOIS-IOWA

A joint meeting of the Illinois and Iowa Sections was held October 10–11, the following papers being presented: "The Iowa Section" by Robert N. Kinnaird; "An Inverted Siphon in a Suction Line" by Karl C. Kastberg; "The Sanitary Drinking Fountain" Prof. J. H. Dunlap; "The Sioux City Booster Station," by Phillip Carlin; "Experience in Handling Bad Water Complaints and Laboratory Control" by Earl T. Kirkpatrick; "Notes and Observations on the Purification of the Missouri River Water at Council Bluffs" by Joseph T. Thornel; "Experience with Trenching Machines on the French and Russian War Fronts" by A. E. Miller; "Swimming Pool Operations" by Jack J. Hinman, Jr.

The following "Round Table Topics" were discussed.

1. Noise of pulsation of disc meters disturbing consumers at night, led by C. H. Streeter.

2. More pumping economy in small plants, led by Charles Chase.

3. Proper charge for services to municipalities, led by C. R. Henderson.

4. Practice in regard to hydrant and valve inspection, led by W. A. Judd.

5. How can water works men assist the State Board of Health in public health work, led by Dr. Bartow.

6. Leaks in river crossings, led by R. N. Kinnaird.

7. Experience in cleaning water mains.

The following officers were elected by the Iowa Section:

Chairman, Charles R. Henderson.

Vice-chairman, S. L. Etnyre.

Directors, Frank Lawlor and Phil. Carlin.

These newly elected officers appointed Mr. Jack J. Hinman, Jr., to act as secretary-treasurer.

On October 11 the members of both sections visited the Rock Island Arsenal, the pumping station of the Davenport Water Company, and of the Rock Island Water Works and also the filter plant; then the Moline pumping station and filter plant, followed by a dinner served at the Moline Commercial Club, after which the meeting was addressed by Mayor Carlson, on the subject of the water supply of the Quad-Cities, Davenport, Rock Island, Moline and East Moline. Mr. Leonard Metcalf, president of the American Water Works Association presented a paper upon the relation of public service commissions to the water works companies. There was a total attendance of ninety-four, and a most successful and enjoyable meeting was held.

MINNESOTA

Meeting for formal organization and election of officers was held in Minneapolis, November 25.

NEW YORK

The eighth meeting of the New York Section was held at the Hotel Astor October 18, the chief feature of which was a discussion of "Sanitation of Water-sheds", opened by Mr. Morris R. Sherrerd, chief engineer of the Newark, N. J. water works, who addressed the

meeting on the "Water-shed Utilized by Newark", illustrated by lantern slides. Mr. Theodore D. L. Coffin presented a paper "Sanitation of Croton Water-shed", also illustrated by lantern slides. This was followed by a paper by Mr. Charles F. Brietzke "Sanitation on the Rockaway River Water-shed", this paper also being illustrated by lantern slides. Discussion on these papers by Dr. William P. Mason, Robert E. Milligan, Allen Hazen, J. M. Diven, Edward Wegman, Alexander Potter, and Morris R. Sherrerd added greatly to the interest of the meeting, which was well attended. Two more meetings will probably be held this winter—one in December and one in February.

COMMITTEES

President Metcalf has appointed the following Committee on Classification of Technical Literature: Mr. Nicholas S. Hill, chairman, Mr. A. P. Folwell, Mr. A. D. Flinn, Dr. Edward Bartow.

This committee is appointed for the purpose of outlining a desirable method of indexing hydraulics and sanitation, and will act in conjunction with similar committees appointed by other technical societies.

OBITUARY

Mr. Henry Floy, Consulting Engineer, New York City, died May 5, 1916.

Mr. Howard D. Newton, Norwich, N. Y., died November 22, 1916.

NAMES ADDED TO THE MEMBERSHIP LIST SINCE LAST ISSUE

Active

C. Cavallier, C. E., Paris, France.

Charles P. Chase, C. E., 123 Sixth Avenue, Clinton, Iowa.

Francis E. Daniels, 1409 N. Front Street, Harrisburg, Pa.

Harry W. Gochnauer, 474 Alton Street, Appleton, Wis.

Henry Hubert Hamley, Brisbane, Queensland, Australia.

Patrick W. Keating, C. E., 504 Ford Building, Detroit, Mich.

Robert McCormick, City Engineer and Superintendent Water Works, Boone, Iowa.

John Peart, Brisbane, Queensland, Australia.

D. P. Porter, 1502 East 8th Street, Pueblo, Col.

George H. Sargent, Superintendent Water Works and City Engineer, LaGrange, Ga.

E. W. Stone, Analyst, 208 Centre Street, Pueblo, Col.

Ellis S. Tisdale, State Department of Health, Charleston, W. Va.

Francis M. Veatch, Superintendent Filter Plant, East St. Louis, Illinois.

Andrew Nelson Wardle, State Department of Health, Charleston, W. Va.

William S. Warner, Chemist and Bacteriologist, City Point, Va.

Corporate

Public Utilities Commission of the State of Colorado, Denver, Colorado.

NOTICE

Members will kindly notify the secretary promptly of any change in address, in order to insure the prompt and correct delivery of mail.

LIST OF OFFICERS 1916–1917

President

LEONARD METCALF, Consulting Engineer, Boston, Mass.

Vice-President

THEODORE A. LEISEN, General Superintendent, Board of Water Commissioners, Detroit, Mich.

Treasurer

JAMES M. CAIRD, Chemist and Bacteriologist, Troy, N. Y.

Secretary-Editor

JOHN M. DIVEN, Superintendent of Water Works, Troy, N. Y.

Trustees

Term Expiring 1917

ALLEN HAZEN, Civil Engineer, New York, N. Y.
ALLAN W. CUDDEBACK, Engineer and Superintendent Passaic Water Company, Paterson, N. J.

Term Expiring 1918

CARLETON E. DAVIS, Chief Bureau of Water, Philadelphia, Pa.
C. H. RUST, City Engineer and Water Commissioner, Victoria, B. C.

Term Expiring 1919

M. L. WORRELL, General Manager Water Department, Meridian, Miss.
F. W. CAPPELEN, City Engineer, Minneapolis, Minn.

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H. E. KEELER	ALLEN HAZEN
GEORGE G. EARL	M. L. WORRELL
NICHOLAS S. HILL, JR.	F. W. CAPPELEN

LIST OF COMMITTEES 1916–1917

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JOHN W. ALVORD, Chairman, 1417 Hartford Building, Chicago, Ill.
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H. E. KEELER, 633 The Rookery, Chicago, Ill.
JOHN M. DIVEN, Editor, Superintendent Water Works, Troy, N. Y.

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D. W. FRENCH, Superintendent Hackensack Water Company, Weehawken, N. J.

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E. E. WALL, Chairman, Water Commissioner, St. Louis, Mo.
GEORGE A. JOHNSON, Consulting Engineer, 150 Nassau Street, New York, N. Y.
FRANK C. JORDAN, Secretary, Water Company, Indianapolis, Ind.
H. HYMMEN, Superintendent Water Works, Berlin, Ont.
GEORGE W. BATCHELDER, Water Commissioner, Worcester, Mass.

ELECTROLYSIS

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CHARLES R. HENDERSON, 114 West Third Street, Davenport, Ia.
DANIEL D. JACKSON, Engineering Building, Columbia University, New York.
E. E. MINOR, Superintendent Water Company, New Haven, Conn.
ROBERT A. JACKSON, Superintendent Water Company, Norristown, Pa.

REPRESENTATIVES UPON NATIONAL ELECTROLYSIS COMMITTEE

D. D. JACKSON, Chairman, Engineering Building, Columbia University, New York, N. Y.
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